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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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The Late Mr. T. H. Firth.

The British foundry industry has suffered a severe loss by the death of Mr. T. H. Firth, who died suddenly last Friday. He had during the morning been to the Brightside Foundry & Engineering Company, of which concern he was chairman, and had a seizure at home during the afternoon. His sudden end came as a great shock to his family and his large circle of friends, not only in Sheffield, but throughout the various engineering centres of Great Britain. Mr. Firth will always be remembered for his geniality and generosity. He gave much of his time to public matters, serving for some time on the Sheffield City Council, but it was public matters associated with the foundry industry which was his favourite work. He was elected president of the Institute of British Foundrymen in 1918, and his address on this occasion, influenced though it was by war memories, marked him as a man with both vision and business logic. He pleaded for a complete dismissal from the mind of worn-out foundry shibboleths, and a concentration upon co-operation between employer and employee to obtain the maximum out of the industry; co-operation between designer and foundryman; standardisation of patterns; specialisation; and the economic co-operation with other units of the British Empire. Since that period these subjects have been discussed with profit in foundry technical societies throughout the world. No more versatile president ever occupied the chair of the Institute than Mr. Firth. He was trained in chemistry, engineering and metallurgy under Professors O'Shea, Ripper and Arnold. He received practical experience in the foundries of J. C. & J. S. Ellis, which was afterwards amalgamated with that of his father—the Brightside Foundry Company. Though he only became chairman of this company some two years ago, on the death of his father, the late Mr. Ambrose Firth, he had for many years represented the interest of the works and the district on the various employers' associations.

In 1922 he visited the United States of America with his closest friend, Mr. Oliver Stubbs, who was that year president of the Institute. Their combined efforts did much to create a feeling of goodwill between not only American business men and those of Great Britain, but also with Europe in general. The fact that something like 100 technical exposés have been interchanged will be lasting memorial to their efforts, and we predict that it is a system which in time will be copied by other engineering and metallurgical societies.

On behalf of the foundry industry, we extend to his family an expression of deepest sympathy which we can assure them will be re-echoed wherever metals are cast.

Some Large Marine Valves.—Part IV.

By Ben Shaw and James Edgar.

Globe valves have a very wide usefulness, and their application is not limited to marine work. They represent, however, a definite type of valve that is used to a considerable extent in marine work, consequently they cannot profitably be omitted from a series of articles dealing with valve castings for the class of work. In considering the preparation of moulds for this type of valve casting, as with all types, the size, design and quantity required have an important bearing on the procedure adopted, there being considerable difference in the preliminary operations, according to whether the valve in its entirety is of a standardised size, or whether alterations are continually being effected, changing the form and direction of the branches without interfering with the standard type of the valve.

While, in a general sense, the principles involved in the preparation of the moulds do not vary to suit the metal of which these valves are cast, yet modifications need to be made to suit

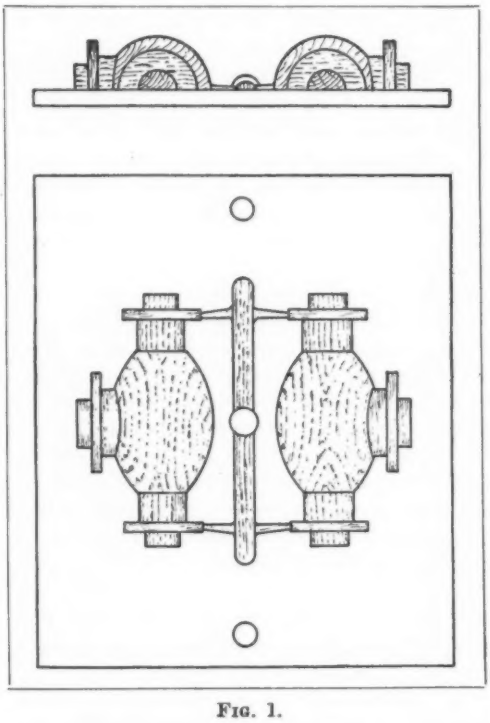

FIG. 1.

the peculiarities of a particular metal or alloy, and much depends upon the quality and composition of the sand used. The nature of the metal required varies with the pressure to which the valve will be subjected and the conditions under which it is required to work. Small globe valves, subjected to low pressures, are frequently made in brass, while medium- and large-sized valves for low pressure are invariably of cast iron. For high pressures, particularly when the castings are of medium size, a bronze mixture is generally used, while, for large valves, steel castings are gradually being introduced when high pressures are involved. Mixtures of metal or alloys used vary, not only to suit the pressures to which the castings will be subjected, but also to suit the work for which they are to be used, whether for air, steam or water pressure, and whether the valves are to be subjected to the influence of fluids and gases. In a subsequent article we purpose dealing with some suitable mixtures of metal or alloys for valves and to discuss differences that are made in moulding valves according to the kind of metal of which they are required to be cast.

When the size of the valve casting is defined and hundreds are required, and the facilities of the foundry permit, the pattern, or a number of patterns, according to the size, may be mounted on a plate and the mould prepared on a hand ramming machine, or the sand consolidated mechanically by a squeezer, by a jolt rammer, or by a combination of the two. This practice is

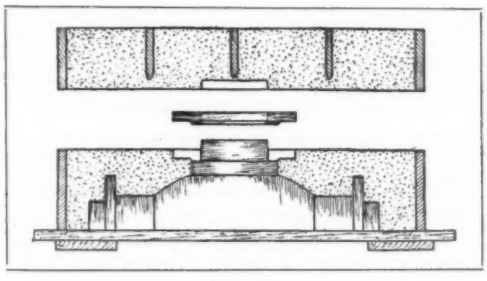

FIG. 2.

more particularly associated with that design of globe valve which has its partitions straight across the body, a design which is common with the smaller valves because there is practically no gain in area by making the partitions circular.

In marine work many globe valves of the straight-through type are required on each vessel for auxiliary steam or/and for water; these are usually of standard size, and vary from 2 in. to 4 in. according to the size of the vessel. In such instances the number of castings required from any definite size generally warrant the use of a pattern plate, preferably for use on a moulding machine, but if a machine is not available the use of such a pattern plate with ordinary hand moulding ensures a more rapid production than by simply using the pattern. For very small valves many patterns can be assembled on a plate, the number being determined by the size of the boxes to be used, but, with the size of valves that have been referred to it is customary to supply only one pattern. The halves of this pattern can be readily mounted on a standard plate, as shown in Fig. 1, to form a reversible pattern plate from which both cope and drag are made, and, when assembled, produce the moulds for two valves. The same method can be adopted for a right-angled valve body when the joints of the branches are on the same plane as the centre of the valve spindle.

The larger globe valve, owing to the reduced number required for each vessel, and to the fact

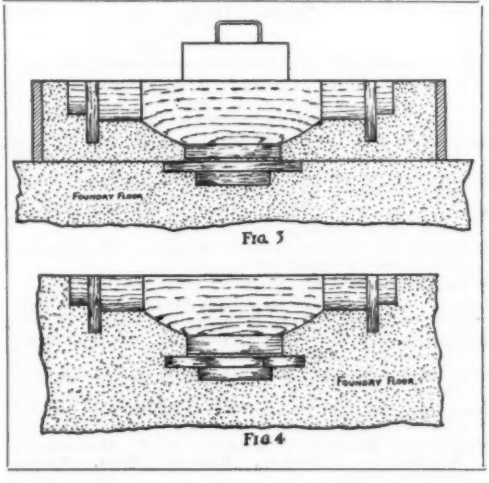

FIG 3

FIG 4

that the sizes and shape of branches vary, generally come under the category of one-off jobs, and although the moulds may be rammed mechanically on a jolting machine, the patterns are not mounted on a plate. Invariably these valve bodies have their division plates concentric with the valve seating, which, for convenience in

stripping, necessitates making the core in two parts. In such instances it is customary to change the direction in which the moulds are prepared so that the assembled parts of the core are not likely to sag or lift with the pressure of metal during the time of casting. As this form of design is generally associated with the larger valves, the patterns are invariably jointed at right angles to

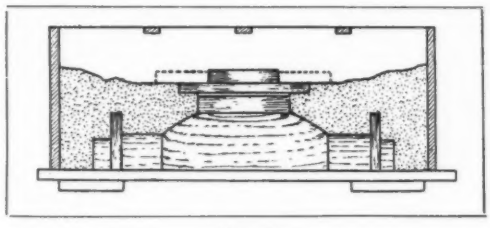

FIG. 5.

the valve spindle. The practice adopted in preparing moulds for these valves in the brass foundry differs from that in the iron or steel foundry, though the principles are similar. In the brass foundry the ramming board is more frequently used, as the moulds are invariably prepared entirely in boxes for convenience in drying, a practice more commonly resorted to than in the iron foundry. A three-part box is generally used and the middle is required to be rammed first. This part should have a depth corresponding approximately to the distance from the pattern joint to the flange on the cover branch, as in Fig. 2. When the pattern section is placed on the ramming board, and the middle box part surrounds it, the sand can be rammed. Careful rodding is necessary to support the sand, particularly if no short bars are cast on the inside faces of the box-part.

The joint is generally formed off the face of the cover flange and raised to suit the box joint, and this is preferable, but sometimes the most suitable box has a middle part that would necessitate a dropped joint if the mould joint is carried off the flange face; it may then be desirable to joint from the back of the flange. The box part to complete the drag may be located on the middle part and rammed up. To save subsequent turning over many moulders strip the cover flange before proceeding further with the mould, replacing the box

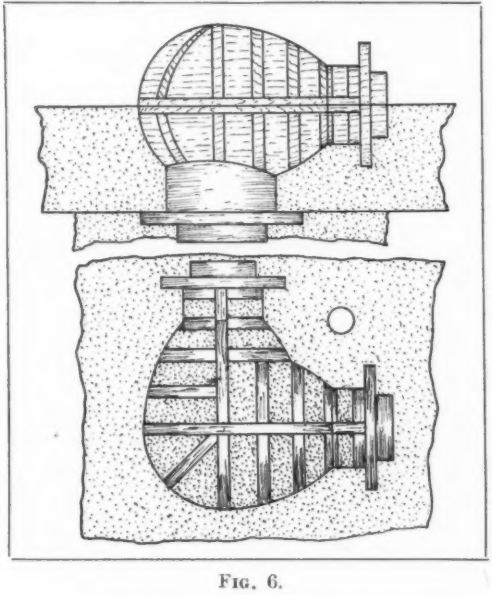

FIG. 6.

part and turning over the whole drag as one part preparatory to ramming the other pattern section to form the cope. This method is the recognised turnover method, which gives better facilities for obtaining a regular density of sand so desirable for the production of clean castings. Although this method is also adopted in iron foundries, it is not so common, a two-part box being more generally used in conjunction with the foundry floor. The manner in which the drag is formed is shown in Fig. 3. The floor is prepared and levelled. It may carry only the core print, being jointed off the cover flange face, or it may be jointed at the back of the flange, as indicated, depending largely on the depth of box part available.

In ramming the drag box part it is advisable to weight the pattern section, and it is just as necessary to rod the sand as in the previous method. Sometimes the whole of the drag is made in the floor, as in Fig. 4. This method may be expedient when the cover flange is very near to the valve body, when a safe lift of a middle part could not be assured without dropping the joint considerably for a box part. This method may also be adopted when a suitable box part is not available. The cover flange must necessarily be loose, and cut for convenience in stripping after the main pattern section has been withdrawn. For this purpose the flange is usually cut into six

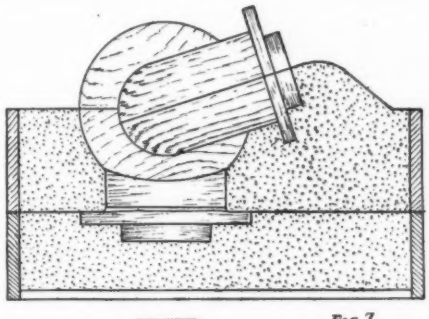

FIG. 7

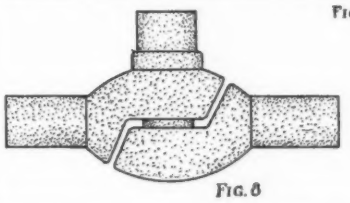

FIG. 8

sections and secured to the core-print, so that they are easily loosened during the time of ramming. One of the flange sections is cut to form a key piece, and it is important to release this piece before commencing the job, in order that the part fitting against the core-print can be marked. This saves much trouble in stripping, because the key piece is the first to be removed. When the cover flange is cut in the manner referred to, a two-part box may be used in order to give greater convenience in drying, but many moulders prefer to adopt a turnover method when the mould is wholly enclosed in a box. The manner in which such a mould is prepared is shown in Fig. 5. A deeper box part is used for the drag, giving at least 3 in. of sand over the highest part of the pattern. Sand is rammed over the pattern section and a temporary joint formed off the face of the cover flange. The cover flange is stripped and the mould faced to finish it while it is accessible. Over the core-print is then placed a previously prepared flat core fitting the core-print and resting on the prepared joint. When this has been set the box part can be completely rammed and turned over to proceed with the cope.

The methods that have been referred to for straight-through valves are not confined to this particular form of globe valve; any one method may be used, according to circumstances, for any form of angled globe valve, providing the branch joints are on the same plane as the body joint. Thus, in Fig. 6, a sectional elevation and plan of the preparation of the mould for a right-angled globe valve is shown. The method of preparation coincides with that shown in Fig. 3, but any of the other methods mentioned may be adopted according to requirements or the facilities of the individual foundry doing the work. A skeleton pattern is frequently supplied for one-off globe valves, when they do not come under the category of standard designs, or where a casting is urgently

XUM

required of an unusual design. Extra work is involved in preparing the pattern for moulding, and generally the mould requires more sleeking when the pattern is stripped. The fact that a skeleton pattern is to be used does not affect the method of moulding; care should be taken in filling up the skeleton shape with sand and in sleeking-off to complete the full shape of the pattern.

The branches on globe valves are not always straight, nor do the joint centres always follow the same plane as the joint of the body. Bent branches are sometimes required at one or both ends of the valve body, and they may be attached at any angle, as in Fig. 7. In this instance the joint of the branch is only slightly altered from the horizontal, and it is only necessary to raise the joint of the drag to correspond.

When preparing the moulds for such valves it is important to observe whether the branches are capable of being loosened from the body for separate withdrawal or whether the flanges are loose. It is better if the branches are loose, and in many instances they need to be. When the angle of the centres of the branches is nearer to the vertical much more labour is involved, but similar methods can be profitably adopted as those described in a previous article under this heading dealing with valve chests. Practically all cores for globe valve bodies that have the internal support for the seating straight through, as shown in Fig. 8, can be formed more conveniently with the joint of the box in the same plane as the spindle. Each half

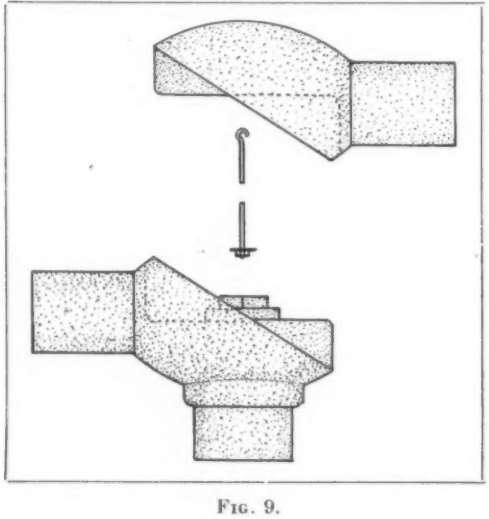

FIG. 9.

of the seating bracket can be withdrawn from the outside or through the core-box, depending upon the construction of the box. It is preferable to fill each half of the core box first, stiffening with irons and grids, according to size, to give strength to the core, and cutting out a small amount of sand from each to act as a vent, after each has been slicked flush with the joint; then an application of starch paste or claywash, or whatever bond may have been used in the core sand, to each joint before the two are brought together will ensure the two adhering. One half-box is removed when stripping, the other retaining the full core until sufficiently stiffened to be lifted out for final drying. The core may be removed from the box at once by using a soft sand bed if a little care be exercised in the process.

When the division plate in the valve is curved and concentric with the seating the making of the core is more complicated. The joint of the box must be made in the opposite direction to that used for the other valves; hence, to enable the withdrawal of the division plate, the core should be separated into two parts at least. Sometimes a half core-box is supplied from which two cores are made, one with the valve branch and one without. A core-print in each half core defines the position core for connecting the two through the division plate. The parts are secured by means of a hook bolt. Generally, however, a full core box is supplied, or part box and strickles, from which the full core can be made. With this type of box the jointing is left to the moulder who prepares the bottom half and cuts out a print before proceeding with the other part. For large cores grids are very necessary, and arrangements must be made for securing the two parts of the core when they have been completed and are ready for assembling. The two part cores are shown in Fig. 9. It will be noticed that a square print is shown, and this is an advantage in preserving the true alignment of the parts, and only one hook bolt need be used to hold them together. Foundries are frequently supplied with core-boxes with the joint plate, forming the partitions left solid, and carrying prints on each side for registering a separate junction core to accommodate the valve seating. Some moulders prefer this form of core-box, but while it is convenient for the medium-sized valve cores, it is not so suitable for large ones. The presence of a substantial grid in large cores necessitates the bedding-in of the joint division plate and, as it is comparatively frail, much time is expended in the operation. The cutting out of the "seating hole," on the other hand, gives access for filling up the box and, after the grid has been set, the plate may be fixed in its correct position, remaining until the whole core has been completed. The latter method certainly necessitates the moulder making his own joint and print for separating and registering the two cores, but, with large valves, there is ample space and less time is involved.

Lancashire Foundrymen Visit Economiser Works.

About 50 members of the Lancashire Branch visited the Works of Messrs. E. Green & Son, Limited, Wakefield, on Saturday, July 11. The visitors were received by Mr. John Haigh, the Foundry Manager of Messrs. Green's and a Past-President of the Lancashire Branch, and were conducted round the Works by the various foremen.

As is well known Messrs. E. Green & Son's Works are admirably well laid out for the manufacture of their product—steam economisers. The foundries are admirably equipped with moulding machines and in the lay out of the foundries considerable attention has been paid to the handling of boxes, patterns, sands and castings. The methods of metal transport also attracted considerable attention.

The visitors were also conducted through the machine shops which are equipped with machines capable of performing the various operations on a repetition basis and the laboratory and testing department were also inspected.

On the conclusion of the visit the party was entertained to tea by Messrs. E. Green & Son, Limited. After tea Mr. J. Masters, the Branch President, spoke of the value of a visit to a works such as Messrs. Green's and a vote of thanks to the Company was moved by Mr. J. S. G. Primrose, Senior Vice-President, and seconded by Mr. R. A. Miles, a Past-President.

At the conclusion of the proceedings several of the members paid an informal visit to the foundry of Messrs. Harrison and Company, Limited, Wakefield, while the majority of the party visited the County Hall, Wakefield, arrangements for the inspection of which had been made by Mr. Haigh.

Other visits which have been made by the Lancashire Branch during the summer include the works of Messrs. Leyland Motors, Ltd., Leyland, which was visited on May 16, and the works of Messrs. Leys Malleable Castings Co., Ltd., Derby, which was the venue of a joint visit with the East Midlands Branch on June 20. Descriptions of both plants have appeared in these columns.

Maxims for Moulders.

Spare the swab and save the job.—*Buchanan.*

Make your plans to suit your "plant."—*Buchanan.*

Dirt and damp can make or mar a mould.—*Buchanan.*

The Influence of Various Elements on Cast-Iron.*

By Matsujiro Hamasumi.

In the present investigation, the white cast iron and the mild steel referred to in the foregoing section were used. The result of the mechanical tests as well as chemical compositions are given in Table I. Except carbon and silicon, the contents of other elements were not analysed; because they can be known from the chemical compositions of the raw materials.

TABLE I.—*Casting Temperature* 1,350° C.

Test No.	Analysis.			Physical Tests.	
	Gr.	CC.	Si.	Max. stress tons per sq. in.	Brinell No.
	%	%	%		
1	3.30	0.54	2.00	7.4	101
2	3.25	0.50	1.91	7.3	101
3	2.97	0.53	1.84	6.9	85
4	2.79	0.63	1.92	7.2	108
5	2.64	0.56	1.89	10.4	114
6	2.49	0.58	1.87	14.3	124
7	1.75	0.70	1.96	22.9	156
8	1.63	0.73	1.79	22.8	179
9	0.95	0.80	1.94	24.7	153
10	0.98	0.86	1.86	24.3	210

The strength decreases with the increase of carbon content. The effect of high carbon is two-fold, that is (1), it causes a high degree of graphitisation, producing many planes of weakness, and (2) it changes the matrix into a hypo-eutectoid composition, while below a 3 per cent. carbon content the matrix is almost eutectoid. Hence the strength of cast iron is a fraction of the amount of graphite when the carbon content

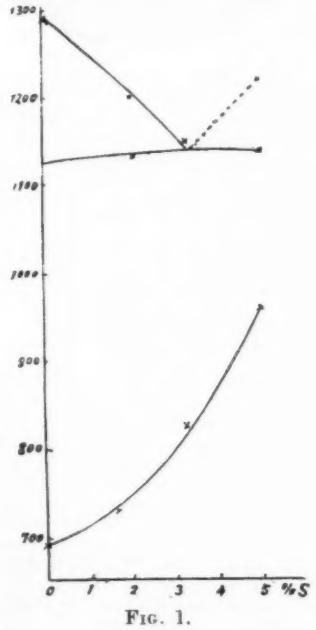

FIG. 1.

is below 3 per cent. The form of graphite flakes changes gradually from platy in high carbon to a nodular form in 1.8 per cent. of carbon specimens.

Effect of Silicon on the Strength of Cast Iron.

A considerable difference of opinion exists among authorities as to the effect of silicon on the mechanical properties of cast iron. Turner's test on the specimens containing 2 per cent. of carbon is frequently referred to by many writers. According to his result, the tensile strength is at a maximum at about 1.8 per cent. of silicon. Hatfield[1] using cast iron containing 3 per cent. of carbon confirmed the fact that the amount of graphite begins rapidly to increase with a content of about 1.5 per cent. of silicon; but the result of his mechanical test is somewhat irregular, no definite conclusion being obtained. Coe's result already referred to chiefly agrees with that of Hatfield, but he did not find the critical content of silicon producing the rapid increase of graphite.

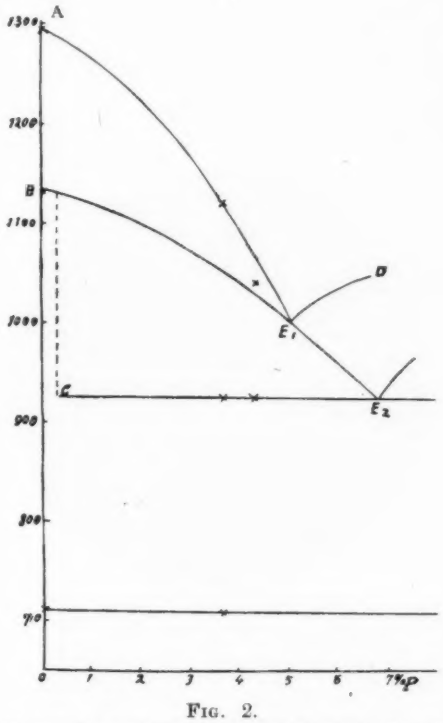

FIG. 2.

It has been shown in the first part that the tensile strength attains the maximum at about 1.8 per cent. of silicon content, which nearly agrees with Turner's result. But this was not the case with the iron cast in a sand mould. Hence another series of tests was carried out in a green-sand mould using the same materials as

TABLE II.—*Casting Temperature* 1,350° C.

Test No.	Analysis.			Physical tests.	
	Gr.	CC.	Si.	Tons per sq. in.	Brinell No.
	%	%	%		
1	trace	2.87	0.15	22.2	262
2	1.80	1.13	0.64	18.4	192
3	1.95	1.05	0.70	18.7	193
4	2.23	0.90	1.15	19.1	186
5	2.32	0.85	1.24	18.9	182
6	2.00	0.73	1.80	18.3	185
7	2.27	0.63	2.27	16.5	155
8	2.76	0.18	2.76	15.2	84
9	2.85	0.12	3.58	13.9	81
10	2.85	0.04	4.18	14.3	103
11	3.00	0.03	5.57	13.6	190

in the foregoing section. The total carbon content was always 3 per cent.

A section of the equilibrium diagram of the iron-carbon-silicon system is shown in Fig. 1, which is reproduced here from Professor T. Murakami's paper. The eutectic concentration of silicon is 3.4 per cent. for 3 per cent. of carbon and the Ar_1 point is raised from 680 deg. C. of siliconless cast iron to 960 deg. C. in a 5 per cent. silicon specimen, which fact is closely related to the complete graphitisation of siliceous irons.

* Extracted from the Science Reports of the Tohoku Imperial University, Sendai, Japan.
† See F.T.J., Vol. XXXI, page 239, *et seq.*

[1] Jour. Iron and Steel Inst. 2, (1903), 332.

The result of the present experiment is tabulated in Table II. With cast iron containing 0.15 per cent. of silicon, although every precaution was taken, no sound specimen was obtained with a green-sand mould. As the microstructure of the sand-cast specimen showed no trace of graphite, the writer used an iron mould to get a sound specimen.

The tensile strength rapidly falls from white cast iron containing 0.15 per cent. of Si, to grey cast iron of 0.64 per cent. Si, and is nearly constant 0.64 to 1.24 per cent. and with a further increase of Si it gradually diminishes. The hardness number varies similarly with the tensile strength with a 3.0 per cent. Si content, but afterwards it rapidly increases up to 5.5 per cent. of Si. The amount of CC. gradually diminished from 2.87 per cent., in which the cast iron to a trace in sample No. 10. This does not agree with the result obtained by Hatfield. The first decrease of hardness to 3.0 per cent. Si content is to be attributed to the differential effect of the reduction of CC. and the hardening effect of silicon in solid solution, while

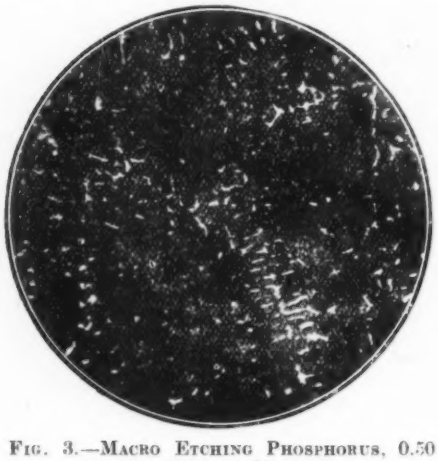

Fig. 3.—Macro Etching Phosphorus, 0.50 per cent. × 80 dias.

the increase after 3 per cent. of Si is due to the prevalence of the second effect upon the first.

Effect of Phosphorus on Cast Iron.

A ternary alloy consisting of iron, carbon and phosphorus has been thoroughly investigated by Dr. Stead[2] and his results have been published in several papers. We cannot too much appreciate his classical work in this special field of metallography. A constitutional diagram was constructed by P. Gœrens[3] based on the works of Wüst, Gœrens and Dobbelstein. Among the papers relating to the influence of phosphorus on the physical properties of cast iron, we may mention those of Turner[4], Johnson[5], Coe[6] and d'Amico[7]. Summing up the results of these workers, phosphorus, when added to steel up to the extent of 1 per cent. considerably increases the tensile strength and diminishes the ductility, but with regard to cast iron, we have some divergent opinions among these investigators. The main feature is that, below 1 per cent., phosphorus strengthens cast iron, but a further addition materially weakens it and makes it brittle.

In his work Hatfield[8] concludes that "there is at present no real evidence that this element materially influences either the degree of hardness or the depth of chill." Dr. Stead says that phosphorus is indifferent to the actual condition of the carbon in pig-iron.

Fig. 2 shows a probable sectional diagram of the system iron-carbon phosphorus containing 3 per cent. of carbon and a varying amount of phosphorus; it is drawn from available data, mainly Gœren's ternary diagram, to give a clear idea of the crystallisation and transformation of these alloys.

[2] Jour. Iron and Steel Inst., 2 (1900), 60, 1 (1915), 175.
[3] Metallurgie, 6 (1909), 540.
[4] Journ. Iron and Steel Inst., 1 (1886), 294.
[5] *Ibid*, 2 (1898), 200.
[6] Jour. Iron and Steel Inst., 1 (1913), 361.
[7] Ferrum (1913), 289.
[8] Cast Iron in the Light of Recent Research, 55.

In Table III the results of the present experiments are given. In this and the following experiments, the grey cast iron containing 3.13 per cent. of carbon and 1.64 per cent. of silicon, referred to at the beginning of this part, was used as raw material, adding a small quantity of ferro-silicon to maintain a content of 1.8 per cent. of Si. In the last column of the table, the machinability of specimens, as examined in actual turning on the lathe, is remarked, and it was found that the hardness of the most suitable machine-casting is from 220 to 240 in Brinel number. The tensile strength considerably increases with phosphorus, up to 0.3 per cent., after which it decreases at first rapidly and then gradually with the increase of phosphorus, while the hardness rapidly increases to 0.5 per cent. and afterward increases linearly.

It is evident from the above sectional diagram (Fig. 2) that these alloys, containing 3 per cent. of carbon, separate primary crystals of austenite on cooling down from the melt to the temperature corresponding to the line AE_1. On a further cooling to the line BE_1, the binary eutectic, consisting

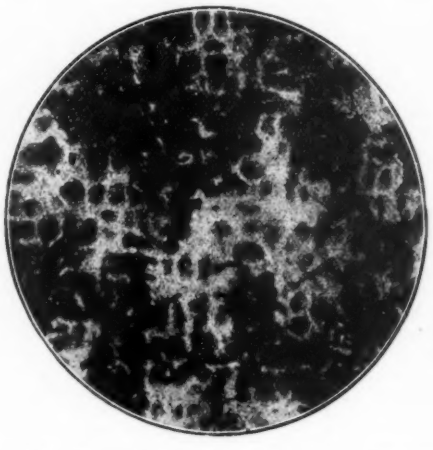

Fig. 4.—Phosphorus, 3.09 per cent. × 80 dias.

of austenite and cementite, simultaneously separates, and finally at temperature of 930 deg. C. a ternary eutectic, consisting of austenite, cementite and phosphide of iron, solidifies, and thus the crystallisation is completed. In the alloys containing less than 0.3 per cent. of phosphorus, the crystallisation ends in the separation of the binary eutectic, and the arrest at 930 deg. C. is absent in these alloys. In the alloys containing more than 5 per cent. of phosphorus, cementite primarily crystallises in the line DE, and then follows the solidification of binary and ternary eutectics.

Strictly speaking there will be a little change in this diagram with the presence of nearly 2 per cent. silicon, but the writer believes that it does not materially alter the constitution of these alloys.

According to Stead, the solid solubility of phosphorus in iron is continuously reduced by the addition of carbon from 1.75 per cent. in pure iron to 0.31 per cent. in cast iron containing 3.5 per cent. of carbon. Specimen No. 4 of the highest tensile strength in Table III contains 0.308 per cent. of phosphorus, the limit of solid solubility of the element; hence it is to be concluded that the first rise of tensile strength is due to the presence of phosphorus in solid solution. By a further addition of the element, free phosphide will separate as a constituent of the triple eutectic, surrounding primarily separated austenite. When the phosphorus content is low, the eutectic lies scattered in the cell boundaries of the austenite; but with an increasing amount of phosphorus, it increases in mass, giving rise to continuous network of phosphide eutectic and finally filling up the interspaces of austenite as the principal constituent in the structure. With this increasing amount of the eutectic in continuous network, the strength of cast iron gradually decreases in virtue of the brittleness of phosphide of iron.

Before entering on a description of the microstructure of these alloys, it is convenient to elucidate first the graphitisation of this ternary system. These alloys, if not graphitised, have three constituents, *i.e.*, austenite in a dendritic form, the binary eutectic as colonies and the ternary eutectic occupying the interstices already solidified crystals. The relative areas occupied by these constituents depend solely on the phosphorus content, when carbon is constant as in the present case. When the content of phosphorus is as low as

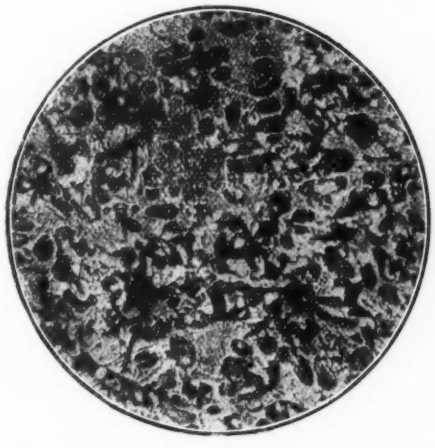

FIG. 5.—PHOSPHORUS, 5.095 PER CENT. × 80 DIAS.

0.3 per cent., the structure consists almost of austenite and Ledeburite, similar to ordinary white cast iron. With an increasing amount of phosphorus, the austenite gradually diminishes, in place of which the binary eutectic increases together with a small area of the ternary eutectic. When the phosphorus content reaches about 5 per cent., the structure consists of binary and ternary eutectics.

The writer holds the opinion that the graphitisation first occurs after the solidification of the binary cementite, the decomposition of which is facilitated by the presence of silicon and further by a slower rate of cooling during the crystallisation of the binary and ternary eutectics. When the phosphorus content is moderate, most of

TABLE III.—*Casting Temperature* 1,350° *C.*

Test No.	Analysis.				Physical Tests.		
	Gr.	C.C.	Si.	P.	Max. stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.33	0.75	1.78	0.026	14.7	175	Very soft
2	2.22	0.71	1.66	0.153	16.5	189	,,
3	2.18	0.85	1.75	0.222	18.3	193	,,
4	2.07	0.80	1.77	0.308	20.0	213	Soft
5	2.10	0.90	1.74	0.504	17.7	195	Good
6	2.15	0.85	1.57	0.670	14.9	202	,,
7	2.36	0.52	1.84	0.342	14.6	204	,,
8	2.30	0.40	1.83	1.132	14.1	207	,,
9	2.22	0.63	1.68	1.806	14.9	210	,,
10	2.35	0.75	1.74	2.056	13.3	202	,,
11	2.10	0.75	1.81	2.775	12.4	216	,,
12	2.05	0.69	1.89	2.552	11.2	212	,,
13	1.92	0.79	1.63	3.090	11.1	227	,,
14	1.95	0.88	1.57	4.173	11.1	230	,,
15	2.10	0.85	1.63	5.095	9.1	226	Hard

the cementite in the eutectics is decomposed, giving rise to the so-called "broken-up-structure" of phosphide eutectic. This is seen from the decrease of combined carbon in specimens Nos. 7 to 12. With an increasing quantity of phosphorus, the amount of the binary eutectic or that of graphite diminishes. The decomposition of the cementite in the triple eutectic is very difficult, as the temperature of its solidification is too low. This is shown by further increase of the combined carbon in specimens Nos. 13 to 15.

The examination of the microstructure of these alloys confirms the above view. When specimen No. 5, containing 0.504 per cent. of phosphorus, is etched with picric acid a network structure appears. By macro-etching, it is clearly shown that this network is made by the chain of phosphide eutectic (Fig. 3).

The graphite flakes in the first five specimens are of a kikumé-structure uniformly distributed. In specimens containing higher per cent. of phosphorus than specimen No. 6, the graphite flakes are thick, platy and irregularly scattered in groups as the decomposition product of the binary cementite needles (Figs. 4 and 5). The ferrite areas are invariably seen around the graphite flakes, indicating the decomposition of cementite at a low temperature. In specimen No. 15, containing 5.09 per cent. of phosphorus, half the area is occupied by undecomposed eutectic, as is confirmed by the heat tinting. In Fig. 6, a micro taken at high magnification, the white portion is austenoidal pearlite, the grey portion cementite and the black patches phosphide of iron. From this fact the excess of combined carbon in the last two specimens of Table III is confirmed. A graphite flake is also seen in the photograph. The austenitic area round this flake is wholly decomposed to phospho-ferrite, while in other portions the lamellar structure of pearlite is clearly observable.

As to the hardness of these alloys, the first increase is due to the phosphorus in solid solution as well as to an increasing amount of free phosphide; but in specimens beyond No. 7 containing 0.84 per cent. of phosphorus, the hardening effect of the phosphide is partially cancelled by the appearance of ferrite due to graphitisation, and hence the hardness increases more slowly than at first.

Effect of Sulphur on Cast Iron.

No systematic investigation of the ternary alloys containing iron, carbon and sulphur has yet been made, so that it is difficult to have a clear idea of the constitution of these alloys. Sulphur is very injurious when contained in steel, and therefore it should be reduced as much as possible, but in the case of cast iron it is a question whether sulphur

FIG. 6.—PHOSPHORUS 5.095 PER CENT. HEAT TREATED × 1,000 DIAS.

has a bad effect irrespective of its amount. Sulphur is the most energetic stabiliser of iron carbide. An addition of 0.2 per cent. of the element to a grey cast iron produces a perfectly white iron; needless to say, this depends on the relative amount of silicon. It is now believed that the above effect of sulphur on cast iron is to be attributed to its chemical nature, and not to the physical or mechanical effect of sulphide of iron.

According to Coe, the strength of cast iron considerably increases with the addition of sulphur. He attributes this effect to the alteration in dendritic structure and to fineness of the graphite in the presence of sulphur. In foundry practice, we rarely meet with cast iron containing more than 0.2 per cent. of sulphur, and hence in these experiments, cast iron containing more sulphur was not investigated; moreover the machining of it presents a further difficulty on account of its great hardness.

Tables IV and V show the result of the present experiments. On casting these alloys, no change in the fluidity of the melt due to sulphur was

observed; but an extraordinary thing was that at the beginning of crystallisation many films in dendritic shape were seen vigorously in motion, which phenomenon was more marked as the sulphur increased in amount. The same phenomenon also occurred in the case of cast iron containing tin. The effect of casting temperature is also very considerable; the test pieces cast at 1,400 deg. C. are stronger in tension from 1.3 to 2.5 tons per sq. in. than those cast at 1,350 deg. C. The writer believes that this is due to the chilling effect of the higher casting temperature, which will be more intensified in cast iron containing sulphur.

TABLE IV.—*Casting Temperature* 1,350° C.

Test No.	Analysis.			Physical Tests.			
	Gr.	C.C.	Si.	S.	Max. stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.14	0.80	1.76	0.018	17.1	187	Very soft
2	1.89	0.84	1.67	0.024	17.6	187	,,
3	2.06	0.84	1.90	0.042	19.2	192	,,
4	1.98	0.77	1.84	0.067	20.3	206	Soft
5	2.03	0.72	1.80	0.086	20.7	204	Good
6	2.13	1.05	1.71	0.125	19.8	209	,,
7	1.93	0.87	1.71	0.144	20.3	223	,,

The tensile strength of the alloys considerably increases to a content of 0.1 per cent. of sulphur, after which it gradually decreases. But the hardness increases nearly proportionally to sulphur: thus the hardness number of specimen No. 9 amounts to 240, which is far greater than in the case of other elements.

On examining the microstructure of these alloys nothing peculiar is observed; the quantity of cementite gradually increasing in accordance with the result of chemical analyses. Graphite flakes are in whirl, no influence of sulphur being observed, and no such change of dendritic structure as was pointed out by Coe is observed. Fig. 7 shows the structure of specimen No. 10,

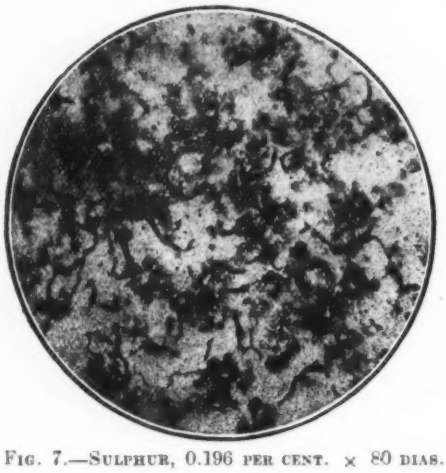

FIG. 7.—SULPHUR, 0.196 PER CENT. × 80 DIAS.

containing 0.196 per cent. of sulphur. At any rate, the presence of about 0.1 per cent. of sulphur is not so detrimental as has hitherto been assumed; on the contrary it is rather favourable in raising the strength of cast iron, when it is contained with some amount of silicon.

Effect of Manganese on Cast Iron.

The effect of manganese on the iron-carbon alloys has been studied by Coe, Wüst,[9] Keep,[10] West and Tereny Jamos.[11] Summing up the results of these investigators, two things are confirmed: (1) manganese in the presence of 2 or 3 per cent. of silicon as in grey cast iron does not retain carbon in the combined state, and (2) with the increase of this element, the pearlitic structure is considerably altered and with a high percentage of manganese the structure becomes sorbitic. As to the effect of manganese on the strength of cast iron, there is much dispute among metallurgists. Thus Keep and Wüst conclude that manganese has little influence on its strength, while Coe shows an increase of 50 per cent. in the strength as a result of the presence of 2 per cent. of manganese. According to Tereny Jamos, the strength of carbon steel increases from 26 tons per sq. in., in 0.3 per cent. manganese to 45 tons in 1.95 per cent. manganese steel.

FIG. 8.—COPPER, 2.64 PER CENT. × 80 DIAS.

Since with an increasing percentage of manganese, the Ar_1 point gradually lowers, till it falls below room temperature, it follows that with an increasing amount of manganese the pearlitic structure changes first to a sorbitic and then to an austenitic structure. Hence it is very probable that the strength of iron increases with the addition of manganese.

Tables VI and VII show the result of the present experiments, which confirm the correctness of the above view. Two series of test pieces were cast; one at 1,350 deg. C. and the other at 1,400

TABLE V.—*Casting Temperature* 1,400° C.

Test No.	Analysis.			Physical Tests.			
	Gr.	C.C.	Si.	S.	Max. stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.00	0.74	1.85	0.019	18.7	189	Very soft
2	2.25	0.77	1.75	0.027	20.0	185	Soft
3	2.11	0.79	1.77	0.049	21.4	210	,,
4	2.14	0.77	1.79	0.067	22.6	209	,,
5	2.10	0.74	1.76	0.087	23.0	223	Good
6	1.82	0.94	1.77	0.100	23.6	221	,,
7	2.04	0.81	1.82	0.120	22.9	226	,,
8	1.75	0.95	1.79	0.124	—	233	,,
9	1.76	1.04	1.87	0.176	21.5	241	,,
10	1.80	1.30	1.80	0.196	21.2	246	,,

deg. C. The results in both series agree well in mechanical properties; consistent with Coe's result, the strength and hardness increase with the percentage of manganese.

The amount of the combined carbon being almost the same, the increased strength of high manganese alloys must be attributed to the change in metallic matrix, *i.e.*, due to the change from pearlite to sorbite. From a practical point of view it is feared that a high manganese cast iron is very hard to machine and is accompanied by a large shrinkage. This may be true when cast iron is chilled white or when it is in an austenitic state due to a high percentage of manganese; but in the presence of 2 per cent. of silicon and with 2 or 3 per cent. of manganese, the anxiety on this account disappears. The graphite in the alloys containing more than 0.5 per cent. of manganese is well in whirl.

It is here to be noted that the alloys have a good casting property, that is, manganese improves the fluidity of the melt, and reduces the dissolution of gases, the most sound casting being thus obtained.

[9] Metallurgie (1909).
[10] Cast Iron.
[11] Stahl und Eisen (1918), 567.

Manganese is therefore one of the best elements occurring in the constitution of cast iron.

Effect of Copper on Grey Cast Iron.

The influence of copper on steel has been frequently investigated from various standpoints; it is generally accepted that up to 2 or 3 per cent., the presence of copper considerably strengthens steel, while it reduces its malleability, causing red-short, in consequence of the combination of copper with sulphur. The effect of copper on cast iron has been scarcely investigated, the only published Paper being that of Lipin.[12] According to

TABLE VI.—*Casting Temperature* 1,350° *C.*

Test No.	Analysis. Gr.	CC.	Si.	Mn.	Physical Tests. Max. stress	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.27	0.74	1.79	0.38	17.5	191	Very soft
2	2.18	0.83	1.73	0.40	18.2	191	,,
3	1.90	0.92	1.89	0.45	18.2	207	,,
4	2.16	0.78	1.86	0.51	19.0	205	,,
5	1.97	0.85	1.54	0.61	18.1	203	,,
6	2.07	0.77	1.78	0.9	20.3	217	Soft
7	1.99	0.87	1.65	1.10	21.7	217	,,
8	2.07	0.75	1.91	1.45	21.2	227	,,
9	1.81	0.92	1.80	1.69	21.9	235	,,
10	2.04	0.74	1.85	2.20	22.2	235	Good
11	2.18	0.70	1.76	2.79	23.7	254	,,
12	1.77	1.03	1.83	3.15	23.6	262	,,
13	1.89	1.17	1.79	3.83	25.9	275	Very hard

him the influence of copper is small as compared with that of other elements; copper increases the fluidity of the melt, the resulting casting being compact and its strength increasing. But in examining the chemical analysis of his alloys, a considerable irregularity is noticed in the amount of combined carbon, varying between 0.11 and 1.12 per cent. Hence the mechanical strength of the alloys containing various amounts of copper are

TABLE VII.—*Casting Temperature* 1,400° *C.*

Test No.	Analysis. Gr.	CC.	Si.	Mn.	Physical Tests. Max. stress	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.08	0.82	1.65	0.15	16.8	175	Very soft
2	2.13	0.76	1.72	0.30	18.7	187	Soft
3	2.15	0.75	1.69	0.46	20.2	198	,,
4	2.10	0.86	1.61	0.69	19.9	196	Very soft
5	2.29	0.75	1.60	0.98	20.4	204	Soft
6	2.04	1.07	1.71	1.34	22.3	220	,,
7	2.25	0.93	1.85	1.88	23.8	233	,,
8	2.00	0.78	1.87	2.49	24.3	232	Good
9	2.24	0,79	1.86	2.60	24.9	249	,,
10	2.34	0.62	1.79	3.16	26.0	262	,,
11	2.07	0.77	1.85	3.94	26.3	271	,,

not comparable with each other, being greatly affected by the combined carbon.

In the present experiments the same material as already described was used, and the casting temperature was always the same; the contents of the elements other than copper were kept constant as nearly as possible. Tables VIII and IX show the results of the present experiment. Thus the strength of cast iron considerably increases with an addition up to 1 per cent. of copper and a further addition does not materially affect the strength; but the hardness gradually increases with the content of copper. Up to 4 per cent. copper is present wholly as a solid solution, and the Ar_2 point and the eutectoid concentration of carbon are little affected by the addition of copper. The form of graphite flakes is also improved by copper, showing a good whirling structure, as seen in Fig. 8.

[12] Stahl und Eisen, 20 (1890), 536.

As to the fluidity of the melt, no marked improvement was observed by the presence of copper; oxide films easily appeared even at a high temperature, and consequently many test-pieces could not be used. Hence a higher casting temperature of 1,400 deg. C. was used for the other series. To the author's regret, the elongation of the alloys was not measured, but their toughness could be seen on actual turning. The graphitisation was not accelerated by copper in the presence of silicon, as is evident from the chemical analyses.

Effect of Chromium on Cast Iron.

The effect of chromium on the strength of cast iron has not yet been studied. According to Hatfield,[13] chromium, when added to cast iron,

TABLE VIII.—*Casting Temperature* 1,350° *C.*

Test No.	Analysis. Gr.	C.C.	Si.	Cu.	Physical Tests. Max. stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.13	0.83	1.79	0.25	17.7	187	Very soft
2	2.08	0.73	1.79	0.33	19.9	201	,,
3	2.20	0.91	1.85	0.45	20.3	196	,,
4	2.20	0.81	1.74	0.65	20.8	196	,,
5	2.18	0.80	1.77	0.91	21.0	229	Soft
6	2.25	0.74	1.81	1.09	21.4	216	,,
7	2.19	0.66	1.83	1.49	20.0	215	Good
8	2.15	0.77	1.88	2.11	20.3	219	,,
9	1.94	0.79	1.82	2.20	20.6	233	,,
10	2.29	0.65	1.85	3.34	19.7	230	A little hard
11	2.07	0.98	1.83	3.88	19.4	248	,,

forms a double carbide of iron and chromium, and enters into both the eutectic and eutectoid structures, the decomposition of cementite being thereby to a great extent hindered. The ferrite in the alloys also contains some chromium as a solid solution.

Lately Professor T. Murakami[14] thoroughly investigated the constitution of iron, carbon and chromium alloys in this institute; he found three double carbides alpha, beta and gamma, having the chemical formula $(Fe_3C)_{10}Cr_4C$, $(Fe_3C)_9\ Cr_4C$ and Fe_3CCr_4C. He magnetically confirmed the conclusion that the alloys containing a small

TABLE IX.—*Casting Temperature* 1,400° *C.*

Test No.	Analysis. Gr.	C.C.	Si.	Cu.	Physical Tests. Tons per sq. in.	Brinell No.	Machinability.
	%	%	%	%			
1	2.08	0.81	1.89	0.23	19.8	199	Soft
2	2.01	0.86	1.80	0.45	20.3	204	,,
3	2.13	0.79	1.78	0.66	21.0	217	,,
4	2.18	0.80	1.79	0.84	21.1	222	Good
5	2.02	0.93	1.72	1.15	21.9	207	,,
6	2.16	0.83	1.74	1.56	21.1	217	,,
7	2.04	0.83	1.75	2.10	21.2	241	,,
8	2.09	0.83	1.73	2.64	21.4	229	,,
9	2.25	0.82	1.72	2.80	22.2	249	,,
10	2.16	0.68	1.78	3.79	22.5	241	,,

amount of chromium have three constituents, namely, ferrite, free cementite and an alpha double carbide; he also ascertained from microscopic investigation a ternary eutectic consisting of austenite, cementite and alpha double carbide. The Ar_1 point is somewhat raised by the presence of a small quantity of the element.

The effect of chromium on the mechanical properties of steel has been studied by Arnold and Read[15] and Guillet.[16] According to the former investigators, the strength of steel containing about 0.85 per cent. of carbon decreases from 43 to 37.7 tons per sq. in. in steels containing from 0.65 to 4.97 per cent. of chromium, while Guillet concludes that the strength of a 0.8 per cent. carbon steel increases from 50.8 to 89.0 tons per sq. in. in steels containing from zero to 5 per cent. of chromium.

[13] Cast Iron in the Light of Recent Research, 95.
[14] Sc. Rep., 7 (1918), 217.
[15] Jour. Ir. St. Inst., 1 (1911), 249.
[16] Rev. Mét., 1 (1904), 156.

Table X and Fig. 19 contain the results of the present experiment. The strength of cast iron is markedly increased by the addition of chromium, its effect being incomparably greater than that of other elements. The fracture of test-pieces containing above 0.9 per cent. of chromium is mottled white and hard to machine. Specimens Nos. 1 and 2 consist wholly of whirling graphite embedded in a perfectly pearlitic ground mass (Fig. 9). Specimen No. 3 contains a small amount of hyper-eutectoid cementite. Graphite flakes in the alloys containing Ledeburite are platy and irregular, as is the case with alloys containing much phosphorus.

TABLE X.—*Casting Temperature* 1,350° *C.*

Test No.	Analysis.				Physical Tests		
	Gr.	CC.	Si.	Cr.	Max. stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.08	0.83	1.54	0.24	21.3	179	Soft
2	2.12	0.80	1.60	0.38	22.2	212	,,
3	1.73	1.10	1.60	0.70	24.1	224	Good
4	1.70	1.23	1.62	0.90	26.0	252	,,
5	1.68	1.41	1.98	1.07	26.4	277	Hard
6	1.72	1.30	1.59	1.50	26.0	286	,,
7	1.73	1.34	1.71	1.80	26.8	287	,,

The result of the microscopic investigation agrees with the structural diagram, although the presence of 2 per cent. of silicon in the alloys modifies their structure in some measure, especially by graphitising free cementite. The cementite separating as the binary eutectic readily graphitises, while the ternary eutectic exists as such, giving rise to the mottled white cast iron. This is confirmed by the form and distribution of the graphite. Whether chromium dissolves in ferrite or not is not yet certain, but it is very probable that it does to some extent.

From the present experiment it is concluded that chromium strengthens cast iron from 16.5 to 22.8 tons per sq. in. in the alloys containing from 0 to 0.4 per cent. of it, without materially altering the structure.

Effect of Tin on Cast Iron.

Tin has been considered to have no useful effect on cast iron, and in our practice the use of tin plate scrap on cupola melting is avoided for fear of its bad effect. But its influence on the mechanical properties of iron has not yet been studied. In the present experiment metallic tin was added to the melt up to 6 per cent., the amounts of carbon and silicon being kept constant. Up to 2 per cent. of tin content there was no trouble in casting test-pieces, but above this percentage a considerable difficulty was met with, owing to its thick fluidity always taking oxide films in the casting and to its extreme brittleness in testing.

TABLE XI.—*Casting temperature* 1,400° *C.*

Test No.	Analysis.				Physical Tests.		
	Gr.	CC.	Si	Sn	Maximum stress.	Brinell No.	Machinability.
	%	%	%	%	Tons per sq. in.		
1	2.09	0.88	1.90	0.2	16.6	208	Good
2	2.17	0.87	1.67	0.4	17.4	219	,,
3	1.89	1.13	1.85	0.8	17.3	245	,,
4	1.80	1.05	1.90	1.2	17.5	254	,,
5	1.71	1.20	1.87	1.6	18.0	270	A little hard
6	1.68	1.46	1.90	2.5	18.3	277	Hard
7	1.66	1.12	1.61	3.0	17.1	270	Very hard
8	1.67	1.07	1.72	4.0	12.6	287	,,
9	1.66	1.61	1.67	6.0	12.3	302	,,
10	1.47	1.27	1.80	6.0	11.7	282	,,

Table XI shows the results of the experiments. The percentages of tin are the calculated values taken in the alloying. A little increase is observed in the tensile strength up to 2 per cent. of tin, above which it rapidly falls to 6 per cent. of the element, while the hardness increases from 208 in a 0.2 per cent. content tin to 300 in a 6 per cent. content. The fracture of high tin alloys shows a brownish grey colour and a very fine structure like that of a hardened tool steel; under the microscope it was found that this structure is due to the hardening of the groundmass. As the content of tin increases, the amount of graphite is gradually reduced, and in high tin alloys fine worm-like flakes are observed.

The present writer also studied the influence of other elements, such as nickel and aluminium. The influence of nickel is found to have no effect up to 2 per cent., but a content of 2.5 to 3 per cent. of nickel somewhat increases its strength. A small addition of aluminium makes the melt thick fluid like aluminium itself, an oxide film always forming on its surface; no sound specimens were obtained.

FIG. 9.—CHROMIUM, 0.38 PER CENT. × 80 DIAS.

SUMMARY.

(1) The strength of cast iron cooled at varying rates has been studied, using iron moulds at different temperatures. It increases considerably with the cooling velocity, the cause of which is principally attributed to the uniformly distributed graphites-in-whirl.

(2) The mechanism of the growth of graphite, especially whirling graphite, has been discussed.

(3) The cause of black fracture and the formation of the network structure in cast iron have been elucidated.

(4) The strength of cast iron rapidly decreases from 2 to 3 per cent. of carbon.

(5) The effect of silicon has been studied up to 5 per cent. of the element. It renders cast iron weak by reducing the combined carbon and increasing the amount of graphite. The amount of graphite gradually increases with silicon.

(6) Phosphorus stiffens cast iron up to a content of 0.3 per cent. A further addition should be avoided in machine casting. The presence of 1 to 3 per cent. of phosphorus in cast iron favours the decomposition of cementite, and above 3 per cent. an increase of combined carbon is observed.

(7) Sulphur strengthens cast iron when added up to 0.1 per cent. Up to this amount it is not detrimental.

(8) The presence of manganese in cast iron is desirable from various standpoints. It improves the fluidity of cast iron: a content up to 3 per cent. does not make cast iron brittle. The amount of graphite is not affected by manganese in the presence of 2 per cent. of silicon.

(9) The presence of copper up to 1 per cent. considerably strengthens cast iron. A further addition up to 4 per cent. has probably no additional effect on the strength. Copper is indifferent for the graphitisation in grey cast iron up to 4 per cent.

(10) About 0.4 per cent. of chromium is very favourable for machine castings that require a great strength. Cast iron is not made brittle by chromium up to this amount.

(11) The influence of tin on cast iron up to 6 per cent. has been studied. Up to 2 per cent. it does not affect the strength of cast iron. A further addition renders cast iron brittle.

Reactions of the Basic Open-Hearth Furnace.*

By T. P. Colclough.

The reactions by which the impurities are removed from a bath of metal in the basic open-hearth furnace are fairly well established, but the order in which those reactions proceed, their relative velocities, and the various controlling factors, are still matters for discussion and research. At first sight the problem appears easy of solution since essentially the process is simply that of the oxidation of varying quantities of carbon, phosphorus, etc., by means of iron oxide. Each of these individual reactions has been studied on the laboratory scale, and the resulting data should be capable of application to the furnace process. Unfortunately, since almost all the products of oxidation are retained in the sphere of operations, the simple reactions are complicated and modified by the following facts:—(*a*) The reactions may proceed, not to completion, but to an equilibrium value or even be reversible. (*b*) Secondary reactions may be set up between different constituents of the system. (*c*) Definite chemical compounds formed by secondary reactions may interfere with the progress or equilibrium of the primary reactions.

Further, in the actual steel-making process, it is not the aim of the melter to attain equilibrium conditions but rather to prevent those conditions being approached until near the time of tapping. Time is an essential and vital element in the commercial process, and the melter works deliberately with an excess of oxide as long as possible, in order to maintain as high a velocity in the reactions as is in accord with other factors of the process. From these considerations, it follows that it is of little value to follow the example of some authors and take isolated samples of slag and metal from different heats and attempt to draw conclusions from calculations made on analyses alone. To obtain data of any value, it is essential that, first, each heat considered must be taken as a whole and every possible detail known, and secondly, the various controlling factors should be modified and the resulting changes noted.

The following data are collected from attempts to study the process on these lines. The primary reactions involved may be expressed simply as follows:—

(1) $Si + 2FeO \rightleftarrows SiO_2 + 2Fe + 65$ Cals.
(2) $2P + 5FeO \rightleftarrows P_2O_5 + 5Fe + 37$ Cals.
(3) $Mn + FeO \rightleftarrows MnO + Fe + 26$ Cals.
(4) $C + FeO \rightleftarrows CO + Fe - 36$ Cals.

In addition the following secondary reactions may be set up:—

(5) $C + MnO \rightleftarrows CO + Mn - 63$ Cals.
(6) $2P + 5MnO \rightleftarrows P_2O_5 + 5Mn - 94$ Cals.
(7) $5C + P_2O_5 \rightleftarrows 5CO + 2P - 220$ Cals.

Further, there are also reactions between the various constituents of the slag yielding definite chemical compounds, and the possibility, or otherwise, of the formation of these compounds exerts a profound influence on the above reactions, *e.g.*:—

(8) $2CaO + SiO_2 = 2CaO \cdot SiO_2$
(9) $4CaO + P_2O_5 = 4CaO \cdot P_2O_5$.

Each of the first three reactions, being of the type of "balanced" reaction, is capable of proceeding in the reverse direction. The problem, therefore, is to determine—(i) the equilibrium constants, if any, for these reactions; (ii) the influence of various factors upon (*a*) these constants, and (*b*) the rate at which the reactions occur. The constitution of the slag is probably *the* most important factor controlling the main reactions (1)-(7). It is impossible, therefore, to deal with the reactions without giving due consideration to the type of slag on the metal.

* A Paper read before a joint meeting of the Faraday Society and the Iron and Steel Institute.

Sources of Oxygen.

The main source of oxygen in the process is the oxide of iron added in the form of iron ore, but, in addition, there is an important oxidising effect of the furnace gases. This is particularly marked during the charging and melting periods when the metal is exposed to the full effect of the flame, but is also proceeding even when the metal is covered with slag. Producer gas always contains considerable amounts of water vapour and CO_2, and both are increased in the furnace by the combustion of the gas. Each of these, and the excess oxygen of the air, is under the prevailing temperature conditions a good oxidising agent. The extent to which this "gas" oxidation proceeds has been indicated previously,* and the data of Table I serve as further evidence. It is important, therefore, to bear in mind that slag and metal are exposed throughout to a powerful oxidising effect, even when ore additions are not being made by the melter. This factor renders all calculations based on oxide additions of very doubtful value.

I.—*Oxidation during Melting.* M. 2,947.

Element.	Charged.	At melting.	Oxidised.	Oxygen required.
	Lbs.	Lbs.	Lbs.	Lbs.
Carbon ..	2,219	576	1,643	2,191
Silicon ..	426	nil	426	487
Phosphorus ..	1,159	429	730	942
Manganese ..	1,430	496	934	272
			Total	3,892

Total oxygen supplied by ore ...	3,107 lbs.	
Oxygen—as oxide of iron—in slag melting	1,674 lbs.	
Net oxygen supplied by ore ...	1,433 lbs.	
Oxygen supplied by furnace gases during melting	2,450 lbs.	

This is equivalent to 63 *per cent.* of the total required, and is about 600 lbs. of oxygen, or 22 *cwts.* of the *ore* used *per hour.*

Silicon.

As would be inferred from thermo-chemical data, silicon is the first element to be oxidised in the basic furnace, and normally the silicon content of the metal is reduced to traces even at the melting stage. The silica thus formed—Equation (1)—rises from the metal to the surface, and combines with the basic oxides, put in with the charge, to form a mono-silicate $2RO \cdot SiO_2$, where RO may be any of the oxides CaO, MgO, MnO, or FeO. So far no case has been recorded of this oxidation of silicon being reversible, as, at the temperatures prevailing, reduction of the silicate does not occur. Under these conditions, the calculation of any value for an equilibrium constant (K_1) for this reaction is impossible.

Carbon and Phosphorus.

From equation (4), $C + FeO \rightleftarrows CO + Fe - 36$ Cals., it will be seen that this is the only one of the primary reactions which is endothermic. From purely thermo-chemical considerations, therefore, this reaction should have the least tendency to occur, and some authorities claim that it is limited to the higher temperatures of steel-making.

Since this carbon reaction yields a product, CO, which is gaseous and escapes from the reaction zone, the equilibrium stage does not depend upon the relative proportions of the constituents, and the reaction will proceed to a point limited only by the solution pressure of CO, or the dissociation pressure of FeO. As both of these are very low, the reaction proceeds almost to completion,

* *J.I S.I.*, 1922, I., 478.

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values of carbon as low as 0.04 per cent. being usual before oxidation ceases, if FeO is available.

From Equation (2), $2P + 5FeO \rightleftarrows P_2O_5 + 5Fe + 37$ Cals., the oxidation of phosphorus should follow that of silicon, and a determination of the equilibrium constant (K_2) be fairly simple. Unfortunately, under the prevailing temperature conditions, the P_2O_5 formed is unstable in the presence of carbon and is liable to attack in accordance with Equation (7), $5C+P_2O_5 \rightleftarrows 5CO+2P-220$ Cals.

This secondary reaction, like No. (4), yields CO as a product and therefore will proceed to a stage depending not on the relative proportions of the constituents, but on the low solubility pressure of CO. This is verified by the facts that the oxidation of phosphorus is impossible in the "acid" process, and only small amounts of phosphorus are oxidised in the basic Bessemer process until the carbon is reduced to very low limits. Hence the elimination of phosphorus is impossible in the presence of carbon, unless by some secondary reaction the P_2O_5 formed is removed from the reaction zone or rendered immune from attack. This is the function of the lime added to the slag, the aim being to form a calcic phosphate which is stable in the presence of carbon [see Equation (9)]. It follows, then, that the oxidation of carbon and phosphorus must be closely inter-related, and the rates at which these elements are eliminated will depend not upon thermo-chemical considerations only, but upon the basicity of the slag.

The three following heats, which are selected as *typical*, and not isolated, *examples* will illustrate the relative importance of these factors.

TABLE II.

Heat – K. 3804.	1	2	3	4	5	6	7	8	9
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	1.4	1.02	0.64	0.26	0.12	0.06	0.04	0.04	0.04
Sulphur	0.033	0.034	0.039	0.045	0.045	0.046	0.045	0.045	0.044
Phosphorus	0.32	0.29	0.23	0.21	0.21	0.14	0.112	0.074	0.038
Manganese	0.42	0.36	0.25	0.24	0.24	0.24	0.22	0.20	0.14
SiO_2	13.8	12.4	12.4	12.4	12.4	11.4	11.4	10.8	9.2
P_2O_5	19.25	19.5	20.24	19.7	19.5	18.8	17.9	17.5	15 5
FeO	5.0	5.14	5.6	5.7	5.78	5.78	6.3	6.8	12.8
Fe_2O_3	2.0	2.8	3.4	3.2	3.3	3.1	3.7	5.1	6.0
Al_2O_3	5.6	—	—	—	—	—	—	—	4.5
CaO	35.8	36.2	36.3	36.6	36.5	36.9	37.9	38.3	39.9
MgO	7.0	7.0	7.0	7.0	7.0	6.72	6.72	5.8	5.2
MnO	10.52	9.5	9.46	9.43	9.43	9.23	8.44	7.58	7.16
S	0.041	0.083	0.110	0.065	0.069	0.056	0.041	0.041	0.041
Molecular Analysis									
SiO_2	0.23	0.2067	0.2067	0.2067	0.2067	0.19	0.19	0.18	0.1533
P_2O_5	0.1355	0.1373	0.1425	0.1387	0.1373	0.1324	0.1260	0.1232	0.1092
Base for $2RO.SiO_2$, $4RO.P_2O_5$	1.002	0.9626	0.9834	0.9682	0.9626	0.9096	0.884	0.8528	0.7434
Base Present:									
CaO	0.627	0.645	0.645	0.652	0.65	0.657	0.675	0.682	0.711
MgO	0.175	0.175	0.175	0.175	0.175	0.168	0.168	0.145	0.13
MnO	0.148	0.134	0.133	0.133	0.133	0.133	0.119	0.107	0.101
Total	0.95	0.953	0.953	0.96	0.958	0.955	0.962	0.934	0.942
Excess Base	–0.052	–0.009	–0.030	–0.008	–0.005	0.045	0.078	0.081	0.198
FeO	0.069	0.071	0.078	0.079	0.080	0.080	0.087	0.094	0.178
Fe_2O_3	0.012	0.017	0.021	0.020	0.021	0.019	0.023	0.032	0.037
$\frac{(Mn) \times (FeO)}{MnO}$	20.0	19.5	14.8	13.9	14.7	15.0	16.4	16.6	25.0×10^{-4}

TABLE III.

Heat – F. 5816.	1	2	3	4	5	6	7	8	9	10
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	1.38	1.34	1.39	1.37	1.36	1.36	1.20	1.17	1,08	1.03
Sulphur	0.029	0.0	0.015	0.010	—	0.010	—	0.010	—	0.010
Phosphorus	0.600	0.464	0.382	0.342	0.231	0.115	0.088	0.052	0.033	0.030
Manganese	0.63	0.94	0.92	0.92	0.86	0.71	0.61	0.52	0.41	0.39
SiO_2	23.6	18.6	16.4	14.8	13.8	12.8	12.0	10.4	9.7	8.9
P_2O_5	8.0	12.1	13.45	13.75	14.55	15.42	14.44	13.88	12.8	10.93
FeO	1.93	0.56	0.36	0.35	1.73	1.96	2.67	3.55	5.56	8.23
Fe_2O_3	4.86	2.66	2.89	3.26	3.14	2.88	4.03	4.06	4.10	5.83
CaO	41.2	48.5	49.9	52.0	51.5	52.0	51.0	50.5	50.8	49.8
MgO	4.32	7.6	8.15	8.07	7.3	6.15	6.15	6.87	6.49	6.15
MnO	14.9	6.4	4.8	4.4	5.22	6.06	7.44	7.35	7.17	7.0
Molecular Analysis.										
SiO_2	0.393	0.310	0.273	0.247	0.230	0.213	0.200	0.173	0.162	0.148
P_2O_5	0.056	0.085	0.095	0.097	0.102	0.109	0.102	0.098	0.090	0.077
Base required for $2RO.SiO_2$, $4RO.P_2O_5$	1.012	0.961	0.925	0.881	0.870	0.864	0.807	0.737	0.684	0.604
CaO	0.732	0.866	0.891	0.929	0.920	0.929	0.911	0.902	0.908	0.889
MgO	0.108	0.190	0.204	0.202	0.183	0.154	0.154	0.172	0.167	0.154
MnO	0.211	0.091	0.067	0.062	0.073	0.085	0.105	0.104	0.101	0.100
Total base present	1.051	1.147	1.162	1.192	1.176	1.168	1.169	1.177	1.176	1.143
Excess Base	0.039	0.186	0.237	0.311	0.306	0.304	0.362	0.439	0.429	0.539
FeO	0.027	0.008	0.005	0.005	0.024	0.027	0.037	0.049	0.077	0.114
Fe_2O_3	0.031	0.017	0.018	0.020	0.020	0.018	0.025	0.025	0.026	0.035

(*a*) K. 3804—Table II—is an example of a heat worked with a "thin" slag, *i.e.*, one of low basicity. The metal at melting had a high-carbon and medium-phosphorus content; iron oxide—as tap cinder—was fed rapidly, but very little limestone was added—merely enough to prevent attack of the banks. It will be seen that the carbon falls rapidly, the phosphorus slowly. Samples 1-5 show that the oxidation of phosphorus is strictly limited—falling from 0.32 to 0.21 per cent., while almost the whole of the carbon is oxidised—falling from

1.4 to 0.1 per cent., *i.e.*, an endothermic reaction takes precedence over an exothermic one, even in the comparatively low-temperature period just after melting.

Further, the oxidation of phosphorus, in each of these Samples 1-5, has proceeded to a definite limit. Each of these slags approaches very closely to the slag composition, previously suggested by the author as the "critical" composition for phosphorus oxidation, *i.e.*, these slags are *saturated* with P_2O_5. From Sample 6 onwards, phosphorus oxidation proceeds rapidly because of the addition of lime and the absence of carbon.

(*b*) F. 5816—Table III—is in marked contrast from the above heat and shows the relative rates of oxidation with a "very thick," *i.e.*, very basic slag. The metal at melting was very high in both carbon and phosphorus. In contrast from (*a*), fluorspar and limestone were added as fast as the slag would absorb them, but no ore was fed until after Sample 4, *i.e.*, the only oxygen available during period 1-4 was that present in the slag at melting, and that furnished by the oxidising effect of the furnace gases. In this heat there is an excess of base in the slag throughout, and (i) Carbon is practically constant for 2½ hours, even for one hour after ore additions. (ii) Phosphorus falls rapidly, and its rate of oxidation is limited only by the amount of oxide available—the FeO being reduced to 0.35 per cent. It is of special interest to note that, under these conditions, the phosphorus apparently attacks the MnO of the slag, in accordance with the Equation (6), $2P + 5MnO \rightleftarrows 5Mn + P_2O_5 - 94$ Cals. (iii) Not until the phosphorus is reduced to low limits is oxide available for carbon oxidation.

(*c*) F. 6124—Table IV—represents a medium course between the two extremes illustrated in (*a*) and (*b*). Limestone and ore were fed in the ordinary way to Sample 1; it will be noted that the oxidation of phosphorus has proceeded to the "limit," the slag being saturated with P_2O_5 and of "critical" composition. Fluorspar, limestone, and a little ore were then added. At first, oxidation of carbon proceeds rapidly while the phosphorus is constant—Samples 1 and 2—but as soon as there is an excess of CaO available to combine with P_2O_5, the oxidation of carbon almost ceases while phosphorus is removed rapidly. Fig. 1 shows the relative rates of oxidation of carbon and phosphorus for these heats.

Consideration of these facts shows that, although from thermo-chemical data it would be inferred that the oxidation of phosphorus would precede that of carbon, in practice the relative rates of oxidation of carbon and phosphorus depend, primarily, upon neither thermo-chemical nor mass considerations, but upon the composition of the slag, *the* controlling factor being the presence or absence of basic oxide to combine with the P_2O_5 as it is formed. The slag is essentially a mono-silicate $2RO \cdot SiO_2$, and whatever base RO, as CaO, MgO, MnO, or to a limited extent FeO, is present in excess of that required for this silicate is available to combine with P_2O_5 to form a stable compound $4RO \cdot P_2O_5$. Given FeO in the

TABLE IV.

Heat – F. 6124.	1	2	3	4	5	6
	3.15	3.30	3.45	4.0	4.15	4.45
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	0.40	0.32	0.31	0.29	0.20	0.14
Sulphur	0.051	0.052	0.052	0.051	0.049	0.046
Phosphorus	0.196	0.194	0.172	0.122	0.094	0.090
Manganese	0.24	0.24	0.23	0.24	0.25	0.24
SiO_2	15.6	15.4	15.0	14.8	14.8	14.0
P_2O_5	18.17	18.17	17.95	17.79	17.79	16.8
FeO	4.24	3.98	3.86	3.31	3.31	4.30
Fe_2O_3	3.6	3.6	3.43	4.6	3.86	3.43
Al_2O_3	3.2	3.3	2.8	2.72	2.69	2.5
CaO	39.6	40.0	43.0	43.6	45.3	46.0
MgO	4.34	4.34	4.34	4.20	3.84	3.84
MnO	9.86	9.55	8.77	8.31	7.89	8.0
Molecular Analysis.						
SiO_2	0.26	0.257	0.25	0.247	0.247	0.233
P_2O_5	0.128	0.128	0.126	0.125	0.125	0.118
Base required for $2RO.SiO_2$, $4RO.P_2O_5$	1.032	1.026	1.004	0.994	0.994	0.938
Base Present:						
CaO	0.707	0.714	0.768	0.779	0.809	0.821
MgO	0.108	0.108	0.108	0.105	0.096	0.096
MnO	0.139	0.135	0.123	0.117	0.111	0.112
Total	1.013	1.012	1.052	1.047	1.062	1.089
Excess Base	–0.018	–0.013	0.048	0.053	0.068	0.151
FeO	0.059	0.055	0.053	0.046	0.046	0.060
Fe_2O_3	0.022	0.022	0.021	0.029	0.024	0.021

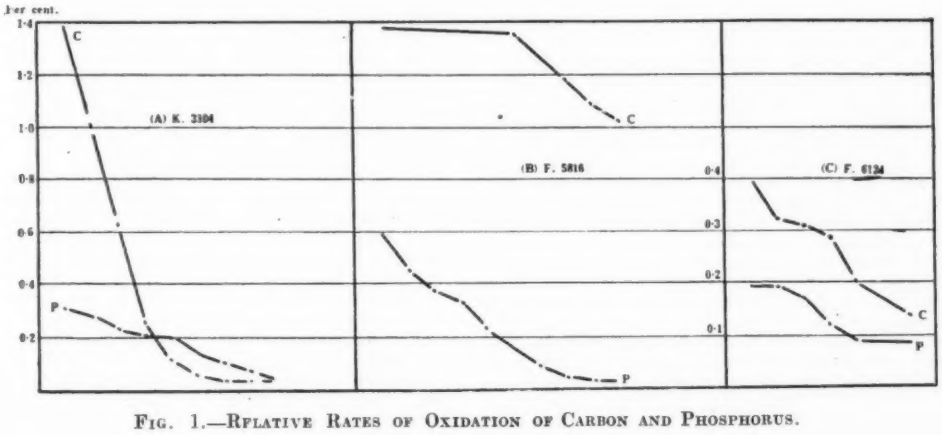


FIG. 1.—RELATIVE RATES OF OXIDATION OF CARBON AND PHOSPHORUS.

slag and a low value of "available" RO, oxidation of phosphorus will proceed up to this limiting or saturation value, and no further; any surplus of FeO will oxidise carbon. If there be a high value of "available" RO, then the reactions are controlled by thermo-chemical and mass considerations, oxidation of carbon practically ceases, and phosphorus is oxidised to the full extent of the oxygen available.

If these conclusions be valid, it follows that in cases like heat (*a*) the distribution of phosphorus between metal and slag is *not* governed by "mass" considerations of Equation (2), and to attempt to calculate values of the equilibrium constant K_2 (as suggested by MacNair) is therefore not only without value, but may be misleading. On the other hand, in heat (*b*), with excess of CaO, there is an opportunity for an equilibrium stage, if such be possible, to be approached in Equations (2), (3), and (6), and values for the respective constants can be calculated.

In making the calculations for these equilibrium constants a further difficulty must be recognised. The formula for the equilibrium constant K applies only to the concentration of the various constituents of a single-phase reaction. In the reactions of steelmaking there are two immiscible phases, the metal and the slag. To calculate the true equilibrium constants, the concentration of the various oxides in the metal phase should be known, and no means, at present, are available to determine this. Since both ferrous and manganese oxides are soluble, to some extent, in the metal as well as in slag, these oxides will obey the Partition Law, and the concentration of each in the metal will bear a certain direct relation to that in the slag. Hence, in all calculations, the concentrations of the oxides in the slag are taken, and these equilibrium values will bear to the "true" values a certain ratio, depending on the partition factors of the oxides concerned.

For example, for the manganese reaction:—

$$\text{Suppose } (FeO)_{metal} = k_1 \cdot (FeO)_{slag} \text{ and } (MnO)_{metal} = k_2 \cdot (MnO)_{slag}$$

$$\text{Then } K = \frac{(Mn) \times (FeO)_{metal}}{(MnO)_{metal}} = \frac{(Mn) \times k_1 \cdot (FeO)_{slag}}{k_2 \cdot (MnO)_{slag}} = \frac{k_1}{k_2} \cdot \frac{(Mn) \times (FeO)_{slag}}{(MnO)_{slag}}$$

$$K_2 = \frac{(P)^2 \times (FeO)^5}{(P_2O_5) \times (Fe)^5}$$

$$K_3 = \frac{(Mn) \times FeO)}{(MnO)}$$

$$K_4 = \frac{(P)^2 \times (MnO)^5}{(P_2O_5) \times (Mn)^5}.$$

The constants K_2, K_3, and K_4 may therefore be calculated from Table III (*a*).

In Samples (3) and (4) conditions are fairly constant and the values given above are in fair agreement, and are probably of the correct order. There may be some doubt as to whether these values of K_2 and K_4 have any *real* meaning, since, under the conditions prevailing, Equations (2) and (6) are not reversible, the P_2O_5 being removed from the reaction zone as fast as it is formed, and also, it is probable that reaction (3) is not at the equilibrium stage but has proceeded beyond it, and is acting from right to left (see section on manganese following).

At this stage it is of value to consider the conditions regulating the return of phosphorus from slag to metal, which often occurs in some basic

TABLE III (*a*).

Sample.	K_2.	K_3.	K_4.
1	8.16×10^{-4}	12.1×10^{-13}	3.33×10^{3}
2	8.23×10^{-4}	9.8×10^{-16}	2.6×10^{6}
3	6.90×10^{-4}	6.5×10^{-17}	4.2×10^{-1}
4	7.3×10^{-4}	4.5×10^{-17}	2.1×10^{-1}

practice. As indicated above, the RO base necessary to form the slag of "critical" composition may be either CaO, MgO, MnO, or FeO. Examination of some hundreds of slag and metal samples, taken at the tapping stage, shows that if there is not sufficient CaO present to completely satisfy both the SiO_2 and P_2O_5 there is grave danger of an increase of phosphorus in the metal on re-carburising in the ladle, *i.e.*, Equation (7) may occur or Equation (2) may be reversible. If the content of CaO alone is high enough to satisfy the needs of the acid constituents there is no evidence of this return of phosphorus, the phosphorus must be in a stable form. Hence, the stability of phosphorus in re-carburising depends upon the basicity of the the slag and has no relation to the state of oxidation of the slag.

On these grounds it is somewhat difficult to understand the suggestion of Whiteley that the FeO content of the slag exerts a controlling effect on the stability or otherwise of P_2O_5. Further, the suggestion of MacNair that "the amount of phosphorus in the metal in equilibrium with a 3.0 per cent. FeO slag is 32 times greater than with a 6.0 per cent. FeO slag of the same P_2O_5 content," can only be accepted with the important reservations that there is (*a*) no CaO or base in the slag available to combine with more P_2O_5, and (*b*) no carbon in the metal capable of reducing P_2O_5. Since such equilibrium conditions are seldom, if ever, realised in practice, such a statement seems devoid of meaning to the practical steel-maker, and indicates a failure to grasp the true factors which control the distribution of phosphorus between slag and metal.

Manganese.

The distribution of manganese, between metal and slag, is a problem on which much discussion has been aroused, and on which there is still conflict of opinion. From the Equation (3), $Mn + FeO \rightleftarrows MnO + Fe + 26$ Cals., it follows that the reaction may be reversible, and should have an equilibrium value, $K_3 = \frac{(Mn) \times (FeO)}{(MnO)}$. In basic practice, the return of manganese from slag to metal has been often observed, and various reasons for it suggested. Naske suggested that the distribution of manganese depends upon the ratio of MnO to FeO in the slag; if the ratio exceeds unity, reduction of MnO occurs, if below unity, then oxidation of manganese proceeds until the equality ratio is established. This does not agree with either practice or theory. In many cases—*e.g.*, Table II—the MnO/FeO ratio exceeds unity throughout, yet there is no reduction of MnO; while theoretically it is clear that the equilibrium depends not only upon the MnO/FeO ratio, but also upon the residual manganese of the metal. Dichmann suggests that the reduction of MnO depends upon the amount of FeO in the slag, and says that the MnO is reduced whenever the FeO falls below 12 per cent., the slag then being poor in available oxygen.

Practical observation shows that the reduction of MnO occurs only when the FeO content is low, as would be deduced from the method of calculating K_3—if FeO falls, then Mn/MnO must rise if K_3 is a constant—but no such limiting value as 12 per cent. can be expected or substantiated. Very few slags, in the author's experiments, approach 12 per cent. FeO, yet the oxidation of manganese proceeds in the normal heats. In heat F.5816, Table III, from Sample 5 onwards the MnO/FeO exceeds unity, and the FeO never approaches 12 per cent., yet there is continued oxidation of manganese, showing that neither Naske nor Dichmann has furnished a satisfactory explanation.

The explanation must be sought in a study of the primary reaction, Equation (3), together with the secondary Equations (5) and (6), and in these latter actions the basicity of the slag is a vital factor. From a study of Equation (3), two important deductions may be made: (i) Since the reaction involves a comparatively small energy change, it will proceed with a relatively low velocity, especially when the manganese is in competition for FeO with elements, like phosphorus, with a greater affinity for oxygen. (ii) If the reaction is proceeding from right to left, the calculated values of Mn × FeO/MnO will be lower than the true equilibrium value, while, if it is proceeding from left to right, the values will be too high.

A first approximation to the value of K_3 can be obtained from a study of samples of slag and metal taken at the "clear melted" stage. At this period, metal and slag have been in contact for some hours and the possible reactions have had a

reasonable opportunity of approaching the equilibrium stage.

Table V gives a list of 10 such samples, and shows a mean value for K_3 of 10.8×10^{-4}.

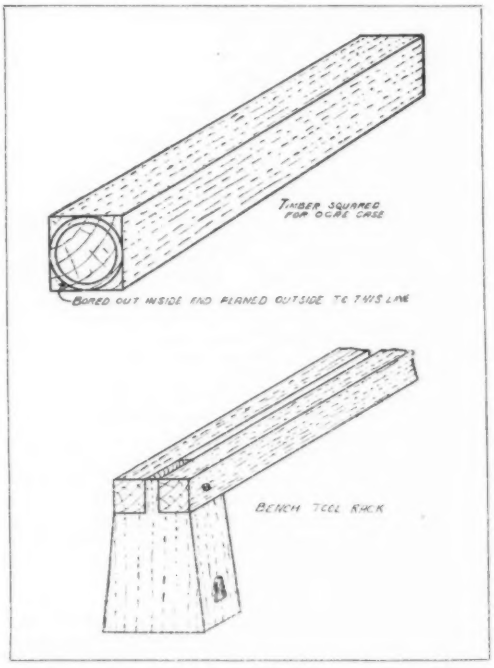
TABLE V.

Heat.	Mn (Metal).	FeO.	MnO.	$\frac{(Mn)\times(FeO)}{(MnO)}$.
	Per cent.	Per cent.	Per cent.	
K . 3810..	0.27	4.56	10.52	11.7×10^{-4}
E . 8019..	0.18	8.55	13.76	11.1
E . 8028..	0.32	3.47	10.54	10.6
E . 8029..	0.33	2.86	7.87	12.0
E . 8045..	0.29	4.76	12.88	10.7
E . 8047..	0.34	5.14	15.4	11.3
M . 3682..	0.29	5.53	14.06	11.4
M . 3685..	0.18	7.33	11.87	11.1
F . 5816..	0.63	1.93	14.9	8.2
K . 4822..	0.27	3.2	8.72	9.9
			Mean	10.8×10^{-4}

(To be continued.)

The Care of Edge Tools.

There are some patternshops in which the stones for grinding plane irons, chisels and gouges are always neglected. The lathes, circular and band saw and planing machine may be kept in excellent order, but, because the grindstone and emery wheels—where such are installed for gouges—are only of indirect value, little attention is given to them. The blunt truth is that cheap and satisfactory production of patterns is not possible with tools that are not in excellent condition and they cannot be so unless the grinding facilities are satisfactory. Patternmakers' edge tools are so



easily burnt that it is imperative that the stone provided should be comparatively soft and the periphery should be turned down at frequent and regular intervals. The older school of men realised the need for good grindstones, and the writer can recollect a strike in a certain patternshop, many years ago, because a new grindstone which was installed was considered to be too hard; it was a "composition" stone, and the patternmakers preferred a natural sand stone. The strike only lasted an hour or two and the firm promised to have a more suitable stone installed.

It is good practice to erect tool racks on patternmakers' benches. These racks should run from end to end of the bench and consist of uprights or standards about 2 ins. thick with two horizontal strips so fitted that there is a long slot for plane and chisels. This slot should be just sufficiently wide for the tool to go through and the ferrule to rest on the top.

Chisels and gouges cannot be maintained in good condition when they are scattered about a bench and as much care is necessary when they are placed in trays in a drawer. Several methods of dividing trays are adopted, but better than any dividing system is the method of making cases for gouges and chisels. The simplest way of making such cases is with brown paper. The tool is first covered with grease. The cases should be at least 2 in. long and the brown paper ought to be cut into strips 4 in. wide. It is then glued on one side and wrapped round the tool and beaten gently with a hammer. The paper is not folded over. When the glue is perfectly dry the case can be trimmed with a sharp chisel and then black varnished. Enough paper should be wrapped round the tool to make a case about 1/16-in. thick, and cases of this kind are permanent and neat.

If a plane iron, chisel or gouge is perfectly tempered, a long bevel is more satisfactory for paring than a short bevel. Patternmakers' paring chucks are different from joiners' mortising chisels which are usually thicker and with a shorter bevel. A sharper edge is obtained with a long bevel. It is as important that the oilstone should be in good condition as the grindstone, and care is not always taken to avoid rubbing the back of the chisel convex and thus spoiling it for accurate square paring. This remark also applies to gouges. It is quite common, nowadays, for an iron stand to be used for the oilstone, but in the writer's opinion nothing surpasses the older box with cover. Sometimes the stone is whiteleaded into such a box, but it is better that it should be a neat fit, so that it can be taken out if necessary. It is always advisable for patternmakers to have a special stone for turning tools or to reserve one side of a stone for turning tools and the other for bench tools.

A word in relation to boring bits. Shell bits, centre bits and what are called ogre bits, are often bunched together in a tray instead of being kept in a cloth pad with separate pockets for each bit. For ogre bits separate hardwood cases should be made. The best method of doing this is to saw a piece of timber 5 or 6 in. long, plane it accurately square, draw centres on each end and bore into it. The outside can then be planed. Such a case should be about 1/16-in. thick and, if varnished, will last for years.

Cast Iron.

The American Foundrymen's Association representative on Committee A-3, the Cast Iron Committee of the A.S.T.M., reports that at the March meeting of this Committee Dr. Richard Moldenke, the chairman, reported results of his recent visit to Europe in which he made a study of the international methods of testing cast iron in various forms. He reported that Germany has adopted a revised test bar for cast iron which is 1.2 in. in dia. and tested on 18-in supports. This bar is one of three standard test bars in England. It has been approved also by a committee of the American Foundrymen's Association with which Committee A-3 has been co-operating. Committee A-3 voted to adopt this revised test bar in place of the present standard arbitration bar and will recommend that it be accepted as tentative at the annual meeting of the Society. Being tested over 18-in. instead of 12-in. supports, the new bar is more sensitive and gives more information on the elasticity of iron than does the present standard bar. The committee is also engaged in a revision of the methods of chemical analysis of cast iron upon which substantial progress will be reported at the annual meeting.

In connection with the matter of specifications for pig-iron, the committee plans a study and tabulation of existing practice in the use of various compositions of pig-iron for different grades of castings.—A.F.A. Bulletin.

New American Specification for Silicon Structural Steel.—At the recent annual meeting of the American Society for Testing Materials new tentative specifications were accepted without discussion, for silicon steel for the main stress-carrying members of structures.

XUM

Institute of British Foundrymen.

Non-Ferrous Metal Session at Glasgow Convention.

For the first time in the history of the Institute a special session was held simultaneously with one on grey-iron foundry practice to discuss two Papers on non-ferrous metals. This was presided over by Mr. V. C. Faulkner (Senior Vice-President), who briefly referred to the innovation of holding such a session separately, and although the attendance was small compared with the iron section, he considered that their deliberations would be highly appreciated by at least one-third of the members of the Institute. He hoped that a similar session would be held next year at the London Conference, and expected it would be presided over by a non-ferrous metal expert.

He then called upon the two authors to deliver their papers, so that the discussion could be taken concurrently. Mr. S. L. Archbutt first introduced his Paper on "Aluminium Alloy Castings," which has already appeared in our pages, 527 and 539 of June 18 and 25 respectively. Mr. F. W. Rowe then enumerated the chief points in his Paper on "The Application of Metallography in Bronze Founding," which has already appeared in FOUNDRY TRADE JOURNAL, pages 491 and 513 of June 11 and 18 respectively.

In inviting discussion upon the two Papers, the Chairman referred to the system which had been evolved during the last two years in various irons, so that by altering one variable with relation to another it was possible always to get down to the same results. In "Y" alloy he asked if it was not possible to alter the composition or constitution in the same or opposite direction and always be sure of the same result. In the case of cast iron they had taken the cooling rate with respect to composition, and for "Y" alloy it might be possible to take something in the manner of rapid ageing and always effect the same result by various heat treatments, which would be of the highest advantage. He considered it would be an excellent idea if the National Physical Laboratory could study the new system and find out if it could be applied to "Y" alloy and others of the aluminium series and change their composition or heat-treatment so that the two could be compared and so arrive at a series of connected variables which would give the standardised results.

In opening the discussion, MR. J. S. G. PRIMROSE considered Mr. Archbutt had very clearly explained the wonderful result of effecting the change in structure and properties of the silicon-aluminium alloy by the process known as modification by use of a suitable flux. He pointed out, however, that the photo-micrographs in Figs. 2 and 3 illustrating this change had inadvertently been both described as "modified," whereas he thought the former was that of the normal structure showing the weakness before the change had taken place. In the same way he hoped Fig. 8 would receive its proper title of photomicrograph of aged "Y" alloy, magnified 500 diams., in order to compare it with the same material differently treated. By splitting the blocks for Figs. 6 and 7 the former had been left without any indication of the composition ordinates, which he presumed were the same as those shown in Fig. 7. He considered the importance could not be over-estimated of what the author had described as careful scientific control of the delicate operations of modifying silicon-aluminium and accelerating the "age-hardening" of "Y" alloy, and pointed out the extremes of over-hardness with loss of ductility, and, on the other hand, excessive softening which were possible if this careful control of temperature were not exercised. Referring to important discovery of the slow solidification method of removing occluded cases from aluminium alloys followed by a quick remelt and then pouring to eliminate pin-holding, the speaker asked Mr. Archbutt if he did not consider the use of an electric melting furnace would be most useful in which to conduct this process of cooling and then reheating to the proper casting temperature, as the control would be simpler than in, say, a coke-fired crucible furnace in which the fire would have to be drawn and then made up again.

Passing to a consideration of Mr. Row's Paper, Mr. Primrose next congratulated that author on the work he was doing in broadening the scope of the practical application of microscopical methods to brass foundry procedure. He considered the splendid Reichert outfit he showed in Fig. 1 was not only useful for making photographic records of microstructures, but was also extremely useful in enabling routine work covering several hundred microspecimens daily to be undertaken in minimum time. He doubted the advisability of trusting to wet alumina for the final polishing of some of the softer constituents shown by Mr. Rowe in his photo-micrographs, as usually some of the finer polishing pastes were better. He asked Mr. Rowe to inform them as to which of the two etching reagents named had been used to develop the structures illustrated and particularly the well-marked coring effects, which appeared to him less marked in the solid solution in Fig. 6 than in the gun metal shown in Fig. 14, illustrating concentric enrichment of the primary constituent. He hoped the author would be a little more explicit in his revised descriptions especially in referring to the several constituents of the phosphor bronzes, *e.g.*, Figs. 16 and 17, as most people were not accustomed to view the copper phosphide at such high magnifications as 2,000 diameters which the author had so successfully achieved with his Reichert outfit.

Annealing of Gunmetal.

In dealing with the question of annealing Admiralty gunmetal at 700 deg. C. as recommended by Mr. H. S. Primrose in 1913, the author had stated that "Why anyone should want to anneal Admiralty gunmetals and bronzes is something of a mystery." There was a very strong financial reason why high pressure castings, often produced at considerable cost, should be annealed after they were found to be leaking from slight porosity due to excessive segregation of the eutectoid, since such treatment made them perfectly water tight, and considerably improved their strength and ductility at the same time. To reduce a wastage of 30 per cent. to 0.3 per cent. in this way was no mean achievement, and the mechanism of the change was no mystery. In view of the difficulty of accurately measuring the temperature of molten metal in the bronze foundry, he asked the author to explain to them the type of thermo-couple or radiation pyrometer which had been used to determine the casting temperatures named in the Paper. He considered the method of using the microscope rapidly to determine the relative amounts of alpha and beta constituents present in a bath of brass already for tapping was a very marked advance upon the old practice of merely judging the fractures of a series of spoon samples.

Micro-etching.

The use made of the examination of the macro-structures of bronze castings to determine when they had been cast at the correct temperature for the work in hand was also an excellent improvement, and was one which should be increasingly adopted for scientific control. He deemed the macrograph in Fig. 26 of the fake in "burning-on" a test bar to a large bronze casting was of the greatest importance in showing the value of this method in bringing home faults to metallurgical wrongdoers.

Segregation of Lead.

MAJOR RHYDDERCH, in referring to Mr. Rowe's paper, asked if the author had found it possible, by the use of nickel, to overcome the difficulty of excessive segregation of lead in the heavily leaded bronzes? He had used nickel to try and stop the very considerable segregation, but when they reached 20 per cent. of lead it became very awkward to obviate getting highly variable results when the castings came to be analysed. He

presumed the author must have had similar experiences, although he only mentioned lower lead contents in his paper. He very much regretted the disclosures made by the macrographs of the cast on test bar, and considered that such things should not be dragged up, for the least said about them the better for the industry.

He expressed great interest in the point mentioned by the former speaker, which was described in Mr. Archbutt's paper as the cooling and then re-heating of aluminium alloys for casting afterwards. He was not quite clear as to the mechanism of this, and would like to know how it is brought about. Did the re-heating not allow the metal to take up gases again? As to the heat-treatment of these aluminium alloys to bring about accelerated age-hardening, especially of castings, it was well known in the steel trade that the structure of castings was very much bigger than in forgings, and to effect a refining at any requisite temperature the time element was the chief consideration. He thought that some such difficulty might arise in connection with the treatment of the aluminium alloy castings, as compared with rolled or forged materials. He thought that there must be some considerable difference between the aluminium ingots "T" and "U" as used to make the "Y" alloys when it behaves so differently. He also asked the author to explain the effect of iron in some of the aluminium alloys named by Anderson in his new book.

Arsenic in Copper.

MR. A. LOGAN considered Mr. Rowe's paper would help on considerably the advancement of scientific work in the brass foundry, and regretted that there were only a small number of foundries which spent much time in going into work of this nature. He thought Mr. Rowe did not sufficiently stress the question of oxides in gun metals, as it was one of the chief impurities usually to be found present, and was so important a matter that it counted for most of the difficulties encountered in making castings of this material. In connection with the author's statement that it was easy to determine the amount of oxygen present in copper by means of the microscope, he would like to ask how he would detect or estimate small amounts of oxygen present in copper containing 0.1 or 0.2 per cent. of arsenic, as it was not always desirable to stick to B.S. brands of copper for ordinary brass founding work. Now that the Admiralty gun metal was specified to have 16 tons per sq. in. tensile strength, he considered that it required the very greatest care in working, and, of course, that made the question of oxides present very important. He considered that 0.1 per cent. of oxygen was low compared with what many firms were using in ordinary copper, which required to be very carefully melted to prevent the occluded gases getting to be several times that amount. In regard to the statement in Mr. Rowe's paper that the limit of solubility of tin in copper being between 6 and 7 per cent. depending on the casting and cooling conditions, he considered that in clean gun metal with very low oxygen content, it was possible to get up to 9 per cent. of tin in solid solution in the alpha constituent without any of the delta eutectoid being formed. This hangs on the question of oxide content, as the more burning the metal has had, the bigger the tendency to form delta, and secondly the greater the chance of getting "bleeding," or what is called segregation, and therefore the poorer the quality of the gun metal. A very practical proposition which had to be fully considered was how to free the gun metal from this excessive oxide, and this made it extremely important to consider the question of adding the tin and the zinc to the copper in their proper order. Mr. Rowe had not mentioned the effect of arsenic upon gun metal, and he asked if the author could give them any information as to the effect of 0.05, 0.1 or 0.2 per cent. of this element when present in gun metal. He was interested in the method described for determining the amount of zinc present in a bath of high tensile brass by means of the micro-structure, but from his own experience in casting a sample from the furnaces into a chill this retarded the formation of the alpha constituent, and unless a series of samples had been prepared in the same condition, he could not see how it was possible to judge the amount of zinc by this method, about which he would like to ask how it was done.

Copper Aluminium Alloys.

MR. LOGAN criticised Mr. Archbutt's paper for not containing any reference to the copper-aluminium series of alloy, more especially as the 10 per cent. alloy had been found extremely useful for marine propeller work, for which purpose it might easily supersede manganese brass, as it was highly incorrodible, and in the meantime only possessed the difficulty of obtaining it sound.

MAJOR RHYDDERCH further contributed to the queries regarding Mr. Archbutt's paper by asking how the molten aluminium alloys were treated. He noticed that the author did not mention what fluxes were used for aluminium alloys, for he considered they might be clarified of objectionable gases by using a suitable covering flux. Referring to the alloy known as alpax, he believed that there was trouble frequently encountered in effecting good machining, and this was usually an important commercial proposition. Then, again, there was the question of the friction set up by some of these soft alloys. As a good pattern metal some one had quoted an alloy containing 93 per cent. of aluminium, with over 4 per cent. of copper, nearly 2 per cent. of lead, and about 1¼ per cent. of silicon, which dragged very badly. He asked if the author could give any practical hint or suggestion as to how this metal could be worked since it was tender when hot and ruptured very easily.

Industrial Application of "Y" Alloy.

MR. MAYBURY considered that in spite of all that had been done, very little had been developed practically in regard to utilisation of "Y" alloy commercially. After a paper to the Automobile Association on this metal it appeared that the reception of the information relating to it had not been very enthusiastic. Although they had heard a good deal about "Y" alloy, it did not appear that very many foundries in this country were producing castings of it in any quantity or of any great size. He declared that most of the figures which were given as tests of the "Y" alloy were obtained from test bars of one inch diameter, which had been cast in a chill, and that we had but little knowledge of the physical properties of the "Y" alloy cast under ordinary foundry conditions. He thought Mr. Archbutt might elaborate that point of the physical properties a little more, and also the application of the heat treatment for accelerated ageing upon the castings themselves instead of the test bars, as there was not much scope for handling such fragile materials when hot.

MAJOR ATHEY said in regard to the question of fluxes raised by Major Rhydderch, he had found that it had been a very difficult proposition effectively to protect molten aluminium alloys from oxidising conditions, but a very useful flux was zinc chloride, although undoubtedly in other countries they had more powerful reagents since they were able to take their refuse and produce aluminium alloys from them.

MR. FAULKNER stated that in regard to the "Y" alloy named in Mr. Archbutt's paper, he thought the N.P.L. had perhaps spent much time and energy needlessly on the question of quick ageing of this material, as they seemed to imagine it was wanted quickly after the castings had been made in the foundry. From what he gathered in the industry, however, they were quite satisfied with the quality of the metal if it acquired its age-hardened properties naturally in about three months' time, which was the period which normally lapsed before the castings were to be put into commission. Another question he raised was in regard to the melting experiments carried out in a neutral atmosphere, because he considered it was more important to have a crucible which would be impermeable by the furnace gases. Much production was spoiled by melting in a clay crucible which was definitely known to be penetrable by sulphur or other gases from the furnace, and he considered that a little research on that line would be difficult, but of great practical value immediately to the industry.

XUM

"Y" Alloy Compared with Aluminium-Silicon Alloy.

MR. F. W. ROWE, like Mr. Maybury, expressed himself as very much interested in the possibilities of the "Y" alloy as distinct from the silicon-aluminium alloy, which required to be modified. His own practical experience pointed to the latter, as he found that it could be produced straight-away without extensive experiments to ensure that the casting conditions were right. Within the 11 to 13 per cent. silicon range, he had found that it was easier to guarantee results than with the "Y" alloy, which took much experimenting to get right. He found that the silicon alloy was extremely simple to make, as the molten metal poured like water, the shrinkage and porosity troubles were very slight, and in addition the machining operation of the solidified castings was very easy and regular. He knew that about 100 tons of this alloy were being produced per week for such varied purposes as motor 'bus wheels, motor-car back axle cases, underground railway carriage doors, etc., and he had not heard of any such wide application of the "Y" alloy. He concluded by asking Mr. Archbutt to give his candid opinion as to which he thought of the two alloys held out the greater commercial proposition.

MR. ARCHBUTT, replying first to the discussion, stated to Mr. Faulkner that the suggestion to vary the composition and adjust the heat treatment to suit was not feasible, as in order to get the best results it was essential to adhere very closely to the composition specified for the aluminium alloys. Of course, it was possible by modification of the heat treatment to get widely varying physical test results. In "Y" alloy, tempering makes it very much harder, and also by suitable higher temperatures it could be made very soft. Thus a tensile strength of 20 tons per sq. in. with only 3 per cent. of elongation could be altered to 10 tons with 13 per cent. elongation. The question of quick ageing of "Y" alloy had been raised by the Engineering Standards Association, whose committee had been dealing with a suitable specification for the material. They had asked if it would be possible to quicken the period taken normally to harden, and thus the usual eight days had been found, on using 100 to 120 deg. C., to be reduced to as many hours. The neutral atmosphere used was that of nitrogen, and it was selected because it was practically insoluble in the aluminium alloys. The author thanked Mr. Primrose for referring to the slight errata and omission, which would be rectified. In regard to the type of furnace used, it had been found possible simply to withdraw the crucible from the furnace, allow it to fall in temperature to about 500 deg. C. very slowly, and then replace in the furnace in order to melt up the contents quickly before much or any gas was reabsorbed. It was also a remarkable fact that in addition to very slow cooling, very quick solidification also overcame the trouble of pin-holing. He explained the mechanism of this change to Major Rhydderch as being that in the slow cooling the gases were thrown out of solution, and were able to escape, due to the metal solidifying sufficiently slowly to permit of this, whereas by the quick cooling, as in chill casting, the gases in solution were not allowed to fall out, and thus there was again no pin-holing. It was the intermediate rate of cooling, such as obtained in making ordinary sand castings, which caused the trouble of pin-holing, which allowed the gases to fall out of solution, but not sufficiently slowly to allow them to get out of entanglement in the metal. He believed the addition of zinc to some of the American aluminium alloys was intended to increase the ductility of the metal, whereas it was usual to consider that the iron increased the strength, particularly at high temperatures, but to exceed the limit of 1 per cent. only increased the founding difficulties very considerably. Complex alloys like that quoted were often used in the United States of America, but he considered it very doubtful if they were any improvement on the straight alloys of simpler composition as used here.

Fluxing Aluminium.

On the question of fluxes he claimed that it was not possible to reduce metallic aluminium from alumina, but only to flux it off. For this purpose zinc chloride was advocated, but it only removed the oxides at the surface, and then there was the danger of getting it into the alloy. To effect a modification of the silicon alloy it was possible to use metallic sodium to do this without the use of the usual flux. In regard to the difficulty of machining Alpax, he believed it was not so great as some people imagined, as they had found no difficulty in machining test bars for their physical test purposes. He believed its ductility was not so good as the "Y" alloy when the latter was properly heat treated. In regard to the complex pattern metal named, with the low copper and about 2 per cent. of lead, he would prefer to recommend the alloy of silicon with aluminium as simpler and less liable to break. Even with the L5 alloy containing higher copper than the alloy named, it would be possible to make a satisfactory job.

In reply to MR. MAYBURY, he contended that he held no brief for "Y" alloy, but merely advised its use in suitable cases because of its excellent possibilities when rightly treated, even if it was not quite so inexpensive an alloy as some others. He declared that it was well known that it was not usually possible to get from castings exactly the tensile or other results obtained from test bars, but there was usually a very good indication of what to expect from the one when the value of the other was known. He instanced a crank case which gave in "Y" alloy an actual tensile strength of 15 tons per sq. in., whereas in L5 alloy the casting only gave about 3 tons per sq. in. As to the suggestion that the castings of complicated shape would lose their shape during heat treatment, it was a simple matter to protect them from distortion by use of a steel jig. Any suggestions as to bettering this would be valued.

The author did not think that there would be much good accruing from the attempt to smelt aluminium out of the aluminium drosses, as it was very difficult except in an electric furnace to reduce the oxide to metal again. Of course, there were fluxes which are of value in melting the skimmings in order to let the finely divided particles of aluminium or alloy coalesce and separate out from the flux, and then this can be melted down into ingot form. Mr. Rowe had suggested that he preferred the aluminium-silicon alloy, and whilst he had to admit that it was an excellent alloy, the question to be considered first was its application, that is, to what purpose was the casting to be put. If the aluminium-silicon alloy was judged on the tensile strength alone it was second only to "Y" alloy, but the best way was to consider the strength to weight ratio, and, moreover, they found that the elastic limit of the silicon alloy was very low, so much so that there is very great distortion at such very low loading as is very frequently applied, and this was a serious objection, so that he did not think they would retain their shape as did "Y" alloy castings. "Y" alloy was not deemed to be a particularly expensive alloy, being only about one penny per pound dearer than the usual run of aluminium alloys, and the possibilities it possessed in its physical properties, more particularly when the necessary care was taken to melt it and further cool it in such a way that the gases were removed before casting. As to Mr. Rowe's objection in regard to sand castings, he considered that the higher temperature of pouring required for "Y" alloy undoubtedly gave rise to greater shrinkage, but that was a matter which could be overcome without much difficulty.

Admiralty Gunmetal.

MR. ROWE, in reply to the discussion of his Paper, expressed his indebtedness for the kind remarks which had been passed upon it. He usually preferred the magnesium oxide to that of aluminium to effect his final polishing, as he had found dimantine to be very coarse and irregular in recent deliveries. As to the question of etching raised by Mr. Primrose, the majority of the figures reproduced had been got by etching the specimen with acidulated solution of ferric chloride, although the ammonium persulphate was useful in bringing out the coring effect,

often very well marked in the phosphor bronzes. He quite appreciated the reasons advanced for annealing Admiralty gun metal, but he brought up the question because this alloy was not fundamentally a good one with which to make hydraulic castings, as it possessed no advantage on the question of strength over alloys which were basically a solid solution. It was best for this purpose to keep the tin content low and have also present sufficient lead to be able to fill up any interstices which might allow of water leakages. The only real reason for annealing Admiralty gun metal he supposed was to ensure better hydraulic tests, and from previous Papers he thought writers had been making too much of annealing to raise the tensile strength and ductility. For temperature control he made use of thermo-couples of two types. The base metal ones for direct immersion in the molten metal, and also the platinum against platinum-rhodium couple for higher temperatures, and, of course, these were provided with a protective sheath.

Major Rhydderch had raised the question of segregation of the leaded bronzes, but he had never had any trouble with the usual run of 8 to 9 per cent. If it were necessary to have more than that very careful control was needed to effect an equal distribution of the lead. He thought 9 per cent. was a maximum used in cases where good anti-friction properties were desired, and even then some care had to be taken in regard to the pouring temperature in order to get good, sound castings. If the temperature fell below 1,020 deg. C. it was often possible to get harmful blow-holes, especially in green sand castings. Above 9 per cent. of lead he knew that nickel was often advocated to ensure uniform distribution of the separated particles, but he had not found so much success with that as with either lead or molybdenum sulphide which had enabled him to get to 18 or 20 per cent. of entangled lead into bronzes. The reason he attributed to his want of success with nickel was that in order to get the nickel into the bronze it might be stewed in the process, as it was difficult to get the nickel completely into solution.

He was pleased to have Mr. Logan's criticism regarding the question of oxides, and fully agreed with him that quite 90 per cent. of the troubles connected with cast gun metals and bronzes were directly traceable to this cause. Zinc and phosphorus added after this impurity had been formed did not remove it completely. Even re-melting did not remove the oxygen, and in fact very few castings were completely free from some traces of oxide, and it was a very easy matter to detect them microscopically in what were considered quite good test bars. He agreed that it was not easy to detect oxygen in copper which also contained small amounts of arsenic. He had no experience of the effect of this impurity upon the properties of gun metal. Especially in melting gun metal in reverberatory furnaces it was important to add the zinc before the tin to ensure that the least possible amount of oxygen was left in the melt. It was an easy matter to allow for the rapid cooling in estimating the amount of zinc in brasses which had to be examined microscopically for their zinc content before tapping, as the effect of retarding the formation of one constituent was quite a regular function.

Solubility of Tin in Copper.

The other point in regard to the solubility of tin in copper was one in which he differed from Mr. Logan, as he had always found even when working with pure tin and copper in the absence of oxygen, that he invariably got some delta separation whenever he passed the 5½ per cent. composition. He quite agreed, however, that oxygen present had a great effect in promoting the separation of eutectoid from the alpha solution, and also the delta was made to separate more completely.

MR. A. B. ROOT, of the Hunt Spiller Manufacturing Corporation, Boston, Mass., U.S.A., has been nominated for the office of president of the American Foundrymen's Association. Similarly Mr. S. W. Utley, of the Detroit Steel Casting Company, of Detroit, Michigan, has been nominated vice-president.

Foundry Accident Prevention.

From time to time we receive Safety-First posters from the National Employers' Mutual General Insurance Association, Limited, of 1, George Street, Mansion House, London, E.C.4, many of which are of the utmost use in inculcating Safety-First sense in the minds of the employees. Accidents cost firms money from the moment they happen, as there is a few minutes' general dislocation, arising from morbid curiosity or genuine regard for a fellow worker. Then there is a further loss of time for first-aid treatment and those who accompany the injured person. This is followed by a certain expenditure of time by way of book-keeping, and, of course, there is always, for anything serious, a loss of wages. All the

factors, however, are not so important as the pain and injury caused to the workman. The Association is doing quite good work in the issuing of these posters, which have shown real improvement since their inception. A new poster is prepared weekly, in order that their usefulness may not be spoilt by staleness and that any value which can be attributed to novelty will be assured. The annual subscription of a guinea we consider to be very modest and if only one accident per year is saved it is well worth the money spent. Other phases of this work are the utilisation of messages imprinted by rubber stamping on pay envelopes, and the inclusion of accident prevention slogans in metal pay boxes. The Association possess a staff of engineers who have specialised in making industrial plant as "safe" as possible, and, we understand, the services of these specialists are gratuitously available for subscribers. A typical poster is illustrated above.

X-Rays in Foundry Practice.

The A.S.T.M. Committee E-4 on Metallography, held a meeting in March. The American Foundrymen's Association representative reports that Committee E-4 discussed the recent development in the study of metals by the use of the X-Ray in which the value of this method of analysis in studying the nature and arrangement of the minute constituents of metals was emphasised. A sub-committee under the chairmanship of Dr. Zay Jeffries of the Aluminium Company of America is engaged in the preparation of recommended practice for making such examinations, and it is expected that this will be a feature of the committee's report to the Society in June.

British Engine, Boiler & Electrical Insurance Company, Limited.—This company (24, Fennel Street Manchester) have now published their Annual Technical Report for 1924. Like those of previous years, it consists of accounts of breakdowns and failures selected from the casualty list of the year, either on account of some interesting peculiarity or as suggestive to makers and users of such plant and machinery as the Company insures.

Commercial Steels.

By C. H. S. T.

The most universal alloying element used in the manufacture of commercial steels is chromium, which has the characteristic function of opposing the disintegration and reconstruction of cementite. This is demonstrated by the critical ranges of this alloy steel taking place slowly; in other words, it has a tendency to raise the decalescent points and to lower the recalescent points. Chromium steels are therefore of great hardness, due to the rapid cooling being able to retard the decomposition of the austenite.

The great hardness of chromium steels is also due to the formation of double carbides of chromium and iron, which condition is not removed when the steel is slightly tempered or drawn, and the additional hardness is also obtained without causing undue brittleness such as would be obtained by any increase of carbon. The degree of hardness of the lower chrome steels is dependent upon the carbon content, as low chromium alone will not materially harden iron.

The toughness so noticeable in chrome steels is the result of the fineness of structure, and in this instance the action is similar to that of nickel, and the tensile strength and elastic limit are therefore increased without any loss of ductility. We then have the desirable condition of tough hardness, making chrome steels extremely desirable for all purposes requiring great resistance to wear, and, in higher chrome contents, resistance to corrosion. All chromium steels offer great resistance to both corrosion and erosion. In view of these facts, it is somewhat surprising that chrome steels are not more used where the metal is exposed to the corroding influences of the atmosphere and moisture.

Prolonged heating and high temperatures have a very bad effect upon chromium steels, and in this respect they differ from nickel steels, though chrome steels will stand higher temperatures than nickel steels when the time of exposure is short.

Chromium steels, due to their property of increasing hardness without loss of ductility, make very excellent chisels and impact tools of all types, though for die blocks they do not give the excellent results that can be obtained from other alloy steels. For ball-bearing steels, where intense hardness with great toughness and ready recovery from temporary deflection is required, chromium as an alloy offers the best solution. Two per cent. chrome steels, due to their very hard, tough surface, are largely used for cold rolls, crushers, drawing dies and similar purposes.

The normal structure of chromium steels with a very low carbon is roughly pearlitic up to 7 per cent. and martensitic from 8 to 20 per cent., therefore the greatest tool steel application is in the pearlitic zone or the lower chromium percentages. Special steels having remarkable wear resisting properties are made from chromium steel in the martensitic zone with about 12 per cent. chromium and very high carbon. Rustless steels contain about the same chromium with low carbon and high silicon.

Nickel Steels.

Nickel is the toughest among the non-rare alloys now used in steel manufacture. Originally nickel was added to give increased strength and toughness over that obtained with the ordinary rolled structural steel, and little attempt was made to utilise its great possibilities so far as heat treatment was concerned. The difficulties experienced have been a tendency towards laminated structure during manufacture and great liability to seam, both arising from a non-homogeneous melt. When extra care is exercised in the manufacture, particularly in the melting and rolling, many of these difficulties can be overcome.

The electric steel furnace of modern construction is a very important step forward in the melting of nickel steel, because neither the crucible nor the basic or open-hearth furnaces gave such good results. It is also necessary that small ingots be made so as to cut down undue piping. In rolling greater care must be exercised in re-heating the billet so that the steel is correctly soaked, and the rolling must not be forced. Too heavy reductions per pass should not be permitted, as these set up a tendency towards seaming.

Nickel steel has remarkably good mechanical qualities when suitably heat treated, and it is especially adapted for case-hardening. It is not difficult to machine low-nickel steel, and it is therefore in great favour where easy machining qualities are of importance.

Nickel influences the strength and ductility of steel by being dissolved directly in the iron or ferrite, in this respect differing from chromium, tungsten and vanadium. The addition of each 1 per cent. of nickel up to 5 per cent. causes an approximate increase of 4,000-6,000 lbs. per sq. in. in the tensile strength and elastic limit over the corresponding carbon steel and without any loss of ductility. The static strength of nickel steel is affected, to some degree, by the percentage of carbon; for instance, steel with 0.25 per cent. carbon and 3.5 per cent. nickel has a tensile strength in its normal state equal to a straight carbon steel of 0.5 per cent., with a proportionately greater elastic limit and at the same time retaining all the advantages of the ductility of the lower carbon.

To bring out the full qualities of nickel steel it must be heat treated, otherwise there is no object in using nickel as an alloy in carbon steel; the additional cost is not justified by the increased strength.

Nickel has a peculiar effect on the critical ranges of steel, the critical range being lowered by the percentage of nickel, and in this respect it is similar to carbon, only more marked. Generally speaking, nickel steel requires a lower heat-treating temperature than chrome steel or tungsten steel, and in this respect is very similar to manganese.

Types of Nickel Steel.

Nickel can be alloyed with steel in various percentages, each percentage having a very definite effect on the microstructure. For instance, a steel with 0.2 per cent. carbon and 2 per cent. nickel has a pearlitic structure, but the grain is much finer than if the straight carbon were used. With the same carbon content and, say, 5 per cent. nickel, the structure would still be pearlitic, but much finer and denser, therefore capable of withstanding shock and having greater dynamic strength. With about 0.2 per cent. carbon and 8 per cent. nickel, the steel is nearing the stage between pearlite and martensite, and the structure is extremely fine, the ferrite and pearlite having a tendency to orientate, as seen in a purely martensitic structure. Carbon 0.2 per cent. and 15 per cent. nickel is entirely martensitic. Higher percentages of nickel change the martensitic structure to austenite, the steel then being non-magnetic.

To obtain the full effect of nickel as an alloy it is essential that the correct percentage of carbon be used. High nickel and low carbon will not be more efficient than lower nickel and higher carbon, but the cost will be much greater. Generally speaking, heat-treated nickel alloy steels are about two to three times stronger than the same steel annealed. This point is very important, as many instances have arisen where nickel steel is incorrectly used, being employed when in the annealed or normal state.

A combination of the characteristics of nickel and those of chromium, as described, should obviously offer a very excellent steel, as the nickel particularly affects the ferrite of the steel and the chromium, the carbon. From such a combination the metallurgist is able to get a very strong ferrite matrix and a very hard, tough cementite. The strength of a strictly pearlitic steel over a pure iron is due to the pearlitic structure being one of layers of cementite running parallel to that of a pure iron layer in each individual grain. The ferrite, *i.e.*, the iron, is increased in strength by the resistance offered by the cementite, which is of the stable iron carbon combination or carbide known as Fe_3C. The cementite, though adding to the tensile strength, is very brittle, and the strength of the pearlite is the combination of the

ferrite and cementite. In the event of the cementite being strengthened, as in the case of strictly chromium steels, an increased tensile strength is readily obtained without loss of ductility; and if the ferrite is strengthened, then the tensile strength and the ductility of the metal is still further improved.

Obituary.

The death of Mr. James Allan Campbell took place on Friday evening, at his residence, 12, Denwick Terrace, Tynemouth, after a short illness. The deceased gentleman, who was in his 47th year, lived on Tyneside for twenty-four years, and had for many years held the position of assistant chief draughtsman at the Wallsend Slipway and Engineering Company. He was keenly interested in the work of the Institute of British Foundrymen, with which he has been connected during the past six years, and was a member of the Newcastle Branch Council. He was also a member of the North-East Coast Institution of Engineers and Shipbuilders.

Mr. T. H. Firth, whose death took place suddenly last Thursday, was chairman of the Brightside Foundry and Engineering Company, Limited, of Sheffield. Mr. Firth was one of the best-known foundry owners in England, as his products covered many fields. He took a great interest in local municipal matters, serving for some time on the City Council. His special interest, however, was the Institute of British Foundrymen, of which Association he was president in 1918. In 1922, in company with Mr. Oliver Stubbs, of Manchester, he paid an extended visit to the United States of America. Mr. Firth was trained under Professors Arnold, Ripper, and O'Shea, and received his practical training at J. C. & J. S. Ellis, a firm afterwards amalgamated with the Brightside Foundry, of which concern his father, the late Mr. Ambrose Firth, was then owner. Mr. Firth was 54 years of age, and is survived by his wife, three sons—Mr. Ambrose Firth, Mr. Graham Firth, and Mr. Jack Firth—and one daughter. A monograph dealing with his career forms the subject of our leading article.

THE LATE MR. T. H. FIRTH.

Foundry Query.

Acid-resisting Bronze.

I shall be glad if you would give me the composition of acid-resisting bronze.

Also please advise us if an acid-resisting bronze can be obtained by adding any metal or alloy to good scrap bronze, instead of using virgin metals.

We might mention that the water in some of the mines in this district is very acid, and we have difficulty in making valves, plungers, etc., to resist the corrosive action of the acid water.—F. ISSELS (Rhodesia).

Cleaning of Castings Regulations.

A number of objections having been received to the draft Regulations under Section 79 of the Factory and Workshop Act, 1901, for the Grinding of Metals* (Miscellaneous Industries), which were issued on February 8, 1924, the Secretary of State consulted with the associations of employers and workers concerned in order, if possible, to arrive at an agreed code and avoid the expense of a public Inquiry, and a number of Conferences were arranged for this purpose. These negotiations lasted a considerable time, but an agreement has now been reached on all the points at issue. A revised draft of Regulations has been prepared to give effect to this agreement and has been accepted by the Engineering and Allied Employers' National Federation and the various other organisations affected.

The agreement involves substantial amendments of the original draft, the chief of which are as follows:—

1. Exemption from the Regulations is given as regards (i) sharpening tools for use in the factory unless done on a considerable scale, (ii) intermittent grinding in which no person is employed for more than twelve hours in any week, and (iii) segmental wheels—see revised definition of grindstone.

2. The power of exemption given to the Chief Inspector of Factories has been extended to cases where the application of the Regulations is found for any reason to be impracticable. This should meet any difficulty which may arise in connection with the application of exhaust ventilation to portable and swinging grinding machines.

3. Regulation 2 dealing with general ventilation and Regulation 5 requiring a supply of clean water and adequate drainage for wet grinding upon grindstones have been made alternative instead of independent requirements. Similarly, if the requirements of Regulation 1 are complied with during the processes of hacking and rodding, as is usual in the case of dry grinding, this will be allowed as an alternative to the provision of adequate water supply in Regulation 6.

4. The requirements as to cleaning (Regulations 7 and 10 (a)) will not apply to any part of the room or fixtures exceeding 14 ft. in height.

5. Regulations 19 and 20 in the earlier draft, dealing with the provision of cloak-room and washing accommodation, have been omitted.

6. In view of the present depressed condition of the metal trades and of the probability that in the near future grindstones of sandstone will be extensively, if not wholly, superseded by abrasive wheels for metal grinding, it is proposed that the operation of Regulations 2, 4, 5 and 6, which may involve structural alterations at the works concerned, shall be postponed for two years.

Before the Secretary of State can make the Regulations in accordance with the revised draft, it is necessary under the provisions of the Factory Act formally to republish the amended draft, and he accordingly gives the following notice: —

That he proposes to make Regulations for the grinding or glazing of metals (other than cutlery or edge tools) and the cleaning of castings, in accordance with the enclosed draft, copies of which may be obtained on application to the Factory Department, Home Office, London, S.W.1, and that any objection with respect to the draft Regulations by or on behalf of any person affected thereby must be sent to the Secretary of State within 21 days of this date (July 21—that is, before August 11). Every such objection must be in writing, and must state (*a*) the draft Regulations or portions of draft Regulations objected to; (*b*) the specific grounds of objection; and (*c*) the omissions, additions or modifications asked for

MESSRS. SAGAR & COMPANY, manufacturers of pattern-making machinery, of Halifax, have suffered a heavy loss through the burning down of the major portion of the works. The damage is said to total £40,000.

MESSRS. F. MILLS, F. WHYATT AND E. H. WHYATT, brass founders, Union Brass Foundry, Beever Street, Oldham, trading under the style of Mills & Whyatt, have dissolved partnership.

* These were outlined in our issue of July 5, 1923, page 3 *et seq.*

Trade Talk.

THE GOLDSBROUGH PATENTS COMPANY, LIMITED, 86, Pilgrim Street, Newcastle-on-Tyne, have removed to the Skerne Works, Darlington.

THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, have secured a contract for two 7,000-kw. turbines from the Hull Corporation.

CAMMELL, LAIRD & COMPANY, LIMITED, Birkenhead, have an order for the construction of three steamers, each of 11,000 tons deadweight, for the Blue Star Line.

THE DIRECTORS of the Coltness Iron Company, Limited, announce that acceptances or applications have been received for a total of 262,500 new ordinary shares at par, recently issued, to be paid in cash.

SERIOUS DAMAGE was caused by an outbreak of fire at the works of Matthew Harvey & Company, iron founders, etc., of Bath Street, Walsall. The fire started in the castings warehouse, and spread to the workshops.

THE CLYDE CRANE & ENGINEERING COMPANY, LIMITED, Mossend, have secured a contract from the Great Western Railway Company for several level luffing jib cranes, in connection with the extension to Plymouth Docks.

THE SHAREHOLDERS of the Rivet, Bolt and Nut Company, Limited, have confirmed the resolution passed at the meeting of the company on June 23 last, with reference to the proposed repayment of 275,000 5 per cent. cumulative preference shares of £1, fully paid, of the company, at par

W. E. BURNAND & COMPANY, electric power engineers, etc., have removed from the Chippinghouse Works, Lowfields, to the Duo Works, 66-106, Shoreham Street, Sheffield. During the removal the maximum stoppage in any department was under 2½ hours. Preparations were made for this, and the final quick move started at the commencement of the dinner hour; the men went to the new works after dinner, and before the afternoon was out, every man was at work again on the job he had left at dinner time.

A LARGE PROPELLER was recently conveyed by the Great Western Railway from Brentford to Barry Docks. It measured 13 ft. 11½ in. on the square, and weighed 8 tons. When loaded slantwise on a specially-fitted "Crocodile" "A" vehicle, the dimensions were :—Leading blade, 13 ft. 5½ in. high at 2 ft. 4½ in. from centre; trailing blade, 13 ft. 9½ in. high at 1 ft. 8½ in. from centre. The excess width in each case occurred on the "6 ft." side. The clearance from rail level to the underside of the lowest blade was 6 in.

IT IS ANNOUNCED that Mr. Arthur Michael Samuel, M.P., the Parliamentary Secretary of the Department of Overseas Trade, has appointed a committee, under the chairmanship of Colonel the Hon. Sidney Peel, to consider the question of insurance against bad debts in export trade. The committee comprises representatives of the banks, accepting houses, insurance companies, Lloyds, the Association of British Chambers of Commerce, the Federation of British Industries, together with the Comptroller-General of the Department of Overseas Trade. The secretary will be Mr. F. H. Nixon, of the Export Credits Department.

THE MOND NICKEL COMPANY, LIMITED, have made an offer of £1,000,000 5½ per cent. mortgage debenture stock at 97 per cent. and £1,250,000 7 per cent. cumulative 'A" preference shares of £1 each. The offer shows that the preference shares (which are offered at 22s. 6d., and are entitled to 22s. 6d. on a winding-up) are covered more than three times by surplus assets, and their dividend requirements are covered over three times by available profits. The capital and interest of the debentures offered are each covered more than six times by surplus assets and profits respectively. The preference shares will rank immediately after the 7 per cent. cumulative preference shares, the market valuation of which is approximately 25s., and in front of £2,000,000 of 7 per cent. non-cumulative preference shares, valued in the market at about par.

COX & DANKS, LIMITED, Ulster Chambers, 168, Regent Street, London, W.1, have just accomplished a piece of salvage work which is somewhat unusual. On July 3, at Scapa Flow, they successfully salved the German destroyer "G.39," which was lying on its side across the "G.86," also lying on its side. It will be appreciated that the task had three features, namely, the disengaging of the two ships, uprighting and lifting, as well as towing into Mill Bay. The tugs towed the floating docks bearing the destroyer between them, and landed the ship in Mill Bay on July 3, as stated. The tugs were then freed, and went out to claim the "G.86," and this vessel was safely beached in Mill Bay on July 14. This means that in four weeks the company have been able to raise two vessels, and expect that before July is out they will have a third, which is really a record. Fifteen destroyers have been raised to date, there being still eleven others.

Company News.

Steel Developments, Limited.—Interim dividend, 3 per cent., free of tax, for six months.

Baldwins, Limited.—Payment of final dividend on both classes of preference shares not recommended.

J. C. Wilson, Limited, Sullington Road, Shepshed, Leicestershire.—Capital £5,000 in £1 shares. Iron-founders.

B. Wright & Son, Limited, 195, Meanwood Road, Leeds.—Capital £10,000 in £1 shares (5,000 6 per cent. cumulative preference and 5,000 ordinary). Engineers

Watteau Works, Limited, The Trading Estate, Slough, Bucks.—Capital £2,000 in £1 shares. Engineers. Directors: W. G. Hatch, F. R. Hatch, T. H. Bray and J. C. Nicol.

Dickinson Good & Company, Limited, Holme Street, Great Grimsby, Lincs.—Capital £5,000 in £1 shares. Ironfounders. Directors: D. Good, Mrs. Kate J. Good and G. D. Good.

Allen & Simmonds (1925), Limited, 42, De Montford Road, Reading.—Capital £10,000 in £1 shares. General, marine and aero engineers, etc. Directors: C. H. B. Fryer and Major R. C. Griffin.

Brasshouse Engineering Company, Limited, 180, Spring Hill, Birmingham.—Capital £3,000 (1,300 6 per cent. cumulative preference). Engineers. Directors: E. L. Hulme, E. Hulme and Mrs. M. H. Hulme.

West Norfolk Engineering Works, Limited, 63-4, High Street, King's Lynn, Norfolk.—Capital £1,500 in £1 shares. Agricultural implement makers. Directors: R. Wharton, A. Mapus-Smith and G. H. Masters.

Furness, Withy & Company, Limited.—Profits, £745,379; dividend on ordinary shares, 7½ per cent., free of tax, which includes bonus distribution 2½ per cent.; depreciation, £200,000; carried forward, £187,259.

New Alldays & Onions, Limited.—Capital £50,000 in £1 shares. Manufacturers of fans, blowers, furnaces, etc. Directors: Sir William D. M. Cotts, Bt., 3, St. Helens Place, E.C.3 (chairman), and Mr. A. T. Cocking, Hartopp Court.

J. G. Vernon & Company, Limited, 19, Bowling Green Lane, London E.C.—Capital £5,000 in £1 shares (1,000 "A" and 4,000 "B"). Engineers and manufacturers of screws, stampings, etc. Directors: Sir George E. Armstrong, Bt., C.M.G., A. E. Tilley and M. V. Ward.

Greenwood and Batley, Limited.—Balance, £27,493; final dividends on preference and ordinary, £12,223; brought forward, £15,270; balance for year to March 31 last, £30,679; depreciation, £6,000; final dividend, 2½ per cent. on ordinary (making 5 per cent. for year); carried forward, £15,501.

Petters, Limited.—Net profit, £25,087; brought forward, £30,884; dividend (less tax) on preference shares for half-year, £5,250; disposable balance, £50,721; dividend on preference shares for half-year, less tax, leaving three years' preference dividend in arrears; transfer to reserve fund, £20,000; carry forward, £24,908.

Parkinson & Cowan (Gas Meters), Limited, Fitzalan Street Works, Kennington Road, S.E.11.—Capital £350,000 in £1 shares (all ordinary). Regulating or measuring apparatus. Directors: Sir Henry Cowan (chairman), F. R. Smith, W. W. Parkinson, J. A. Macleod, Sir William S. Haldane, B. R. Parkinson and F. Thorp.

Contracts Open.

Bristol, August 10.—Cranes, in the western arm of the Royal Edward Dock, Avonmouth, for the Docks Committee. Mr. T. A. Peace, chief engineer, Port of Bristol, Chief Engineer's Office, Avonmouth Docks. (Fee, £3, returnable.)

Johannesburg, August 22.—Supply and delivery of one gas-fired tilting furnace and one moulding machine, for the Municipal Council of Johannesburg. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1, quoting reference A.X. 2186.

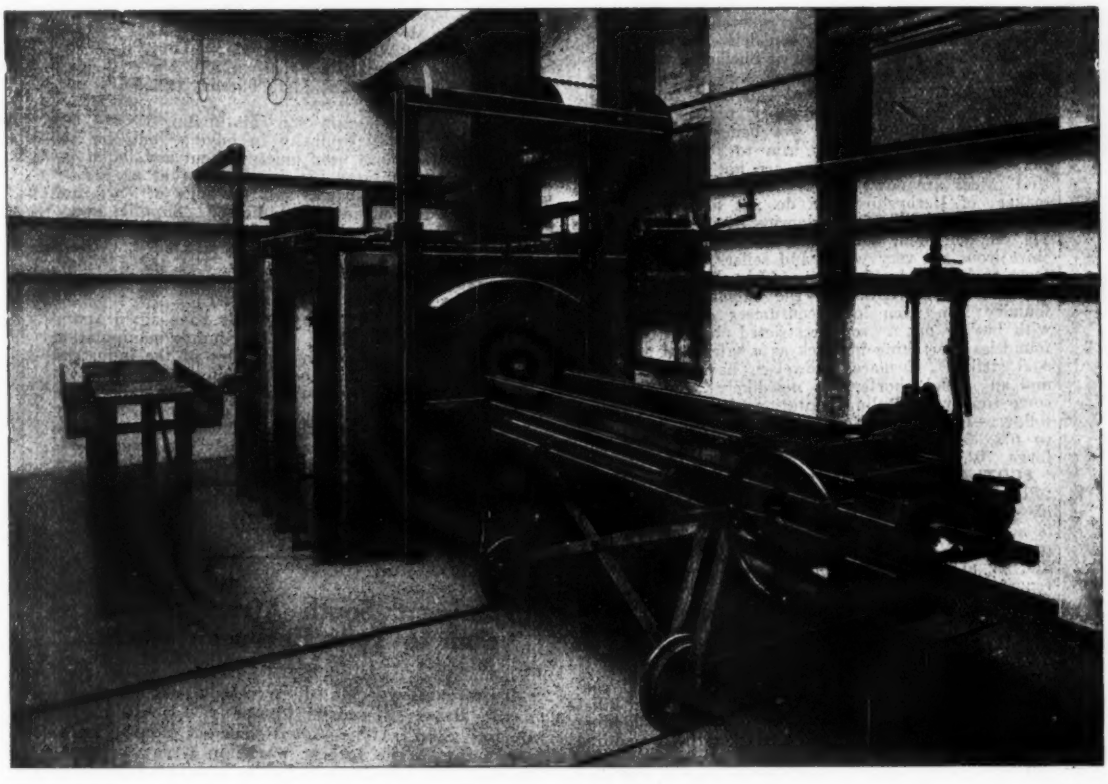
Sydney.—Aluminium, bronze, brass tin, zinc, monel and nickel wire, for a local firm in Sydney. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1, quoting reference A.X. 2190.

Prescot, Lancs.—Pumping plant, at Prescot, Lancashire, for the Liverpool Corporation. Mr J. R. Davidson, water engineer, 55, Dale Street, Liverpool. (Fee, £2 2s., returnable.)

THE TRENT IRON COMPANY, LIMITED, Scunthorpe, (John Brown & Company, Limited) have closed down.

MR. R. B. HODGSON, general manager and director of Ashmore, Benson, Pease & Company, Limited, Stockton, who is taking up a similar position with the Whessoe Foundry & Engineering Company, Limited, Darlington, has been the recipient of presentations from officials and men.

HEAT TREATMENT
UNDER
IDEAL CONDITIONS



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IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Business in the Cleveland iron market during the past week has, on the whole, maintained a steady tone, although transactions have been mostly confined to purchases on a moderate scale, usually to meet immediate needs of consumers. A more favourable feature at the moment is an increased inquiry from abroad. There is always a proportion of foreign users who will buy Cleveland iron in preference to Continental makers, if the difference in price be not too great, and the present margin is such as to encourage this class of buyer. With regard to prices, the quotation for No. 3 G.M.B. holds firm at 71s. per ton. No. 1 is offered at 75s., No. 4 foundry at 70s. 6d., and No. 4 forge at about 70s. per ton.

The market for hematite is fairly steady. On the whole the outlook is a little more encouraging, and this is reflected in the quotation for East Coast mixed numbers, which remains pretty firm and unchanged at 77s. per ton, with No. 1 quality at 77s. 6d. per ton. In the North-West area prices are unchanged, with Bessemer mixed numbers quoted at £4 5s. c.i.f. Welsh ports, £4 8s. 6d. per ton delivered at Glasgow, £4 12s. 6d. per ton delivered at Sheffield, and £4 15s. per ton delivered at Birmingham.

LANCASHIRE.—The local markets for foundry pig remain in the unsatisfactory position previously reported, ironfounders not yet being inclined to do more than order sufficient iron to keep them going for a week or two, as they are not at all sure yet that prices are down at the bottom. It is true that makers of Derbyshire iron do not admit that it is possible to put the furnace price down below 70s. or 77s. 6d. delivered, but Northamptonshire and Lincolnshire irons are very weak, and sellers of these brands seem to be squeezable to a considerable extent.

THE MIDLANDS.—At the moment demand for foundry iron from local consumers continues weak, with buying on a very restricted basis, but some foundries are taking in stock as a safeguard against a coal strike. Furnaces, however, have large stocks, and an actual shortage is not likely to develop for some time yet. Ruling quotations for pig-iron are as follow:—Derbyshire No. 3 foundry, 70s.; forge, 65s. to 67s. 6d.; Staffordshire No. 3 foundry, 72s. 6d.; forge, 70s.; Northants No. 3 foundry, 65s.; forge, 60s.

SCOTLAND.—With the Glasgow Fair holidays in full swing, most of the works in the district will be closed for ten to fourteen days. Consequently there is a further contraction in the volume of business passing. No. 3 Scotch foundry iron is quoted at 81s. 6d. at the furnaces, but practically no business is reported.

Steel.

At Sheffield the depression in the steel market continues without relief, neither acid nor basic billet buying having improved. Users are clearly holding back and watching the trend of markets before adding to their commitments. The output of finished basic steel is at a low ebb; in fact, worse than at any time since its production on a considerable basis in this district. Belgian soft billets have been done at as low as £4 15s. f.o.b., and it is reported that Welsh makers, who continue very badly in want of work, have been tempted to take less than £6 10s., and where the nature of the contract has suited them they have done so.

Scrap.

The outlook for the trade in scrap metals at the moment could hardly be worse, the present demand from the ironfoundries for ordinary cast scrap being both poor and intermittent, and for common qualities only about 72s. 6d. per ton is paid. There is, however, still a very great scarcity of fine cast scrap from broken textile machinery, and for this comparatively high prices can be obtained. Lancashire founders who have special work requiring extra good castings which need Scotch iron want this fine quality of scrap to save them from having to pay the higher Manchester price for Scotch pig; and it suits them to take it, even at 10s. per ton more than ordinary common scrap. There are, however, not very many ironfounders who have orders of this kind in hand, and it is only the scarcity of textile scrap which keeps the price up. In the Scottish area deliveries of scrap material have been practically suspended over the holiday fortnight, and it is questionable whether any revival of demand is probable before the later autumn at the earliest. In the meantime quotations for cast-iron scrap for foundry use remain weak and irregular.

Metals.

Copper.—Following an improvement in New York advices last week, movements in standard copper values have assumed a steady upward tendency, with a distinctly firmer undertone. At the same ime there is a considerable potential demand, as it seems that there is a possibility of various European countries proceeding with electrification schemes despite financial stringency. Current quotations:—*Cash*: Thursday, £61 15s.; Friday, £61 17s. 6d.; Monday, £62; Tuesday, £62 2s. 6d.; Wednesday, £62 5s.

Three Months: Thursday, £62 15s.; Friday, £62 17s. 6d.; Monday, £63; Tuesday, £63 2s. 6d.; Wednesday, £63 5s.

Tin.—Further consideration of the figures in the statistical returns has induced a more favourable view of the tin position. Were it not for the unsettled state of industry generally in this country values would undoubtedly go ahead. Production naturally tends to increase, being largely due to the comparatively high prices for the metal which have been ruling for such a long period. From the statistical position, however, it is to be assumed that supply and demand are keeping very close together. Current quotations:—*Cash*: Thursday, £258 10s.; Friday, £260 15s.; Monday, £261 5s.; Tuesday, £261 7s. 6d.; Wednesday, £262 15s.

Three Months: Thursday, £260 15s.; Friday, £263 5s.; Monday, £263 15s.; Tuesday, £263 17s. 6d.; Wednesday, £265 7s. 6d.

Spelter.—The market for this metal of late has developed some irregularity in buying, but, on the whole, business has been quiet without any important changes in quotations. It is argued that at present prices look high enough, and the idea of curtailing production is inclined to be ridiculed. Supplies everywhere are ample, and zinc would probably break very badly if it were not artificially supported. Current quotations:—*Ordinary*: Thursday, £34 15s.; Friday, £34 17s. 6d.; Monday, £34 18s. 9d.; Tuesday, £35 6s. 3d.; Wednesday, £35 13s. 9d.

Lead.—Values of soft foreign pig have again appreciated to a small extent, chiefly due to manipulation and interested support, but in view of the industrial outlook, the metal must be regarded as too high. It would be futile for operators to try to ignore the serious industrial position that is developing, not only in this country, but elsewhere. At the same time the cable makers remain comparatively well employed, and house-building is certainly quite active. Current quotations: — *Soft foreign (prompt)*: Thursday, £34 7s. 6d.; Friday, £34 13s. 9d.; Monday, £34 15s.; Tuesday, £35 2s. 6d.; Wednesday, £35 7s. 6d.

Prominent South African Foundryman to Tour European Works.

Two years ago, Mr. J. W. Hobbs, of the Standard Brass Foundry Company, Limited, of Benoni, South Africa, spent some six months visiting many of the largest works in Great Britain. During this period he closely associated himself with the work of the Institute of British Foundrymen, and took part in the Paris International Foundry Congress. His charming personality attracted to him many friends. On his return home, he felt that he had derived so much benefit from his trip that, on his advice, his chairman, Mr. A. Moore, decided to revisit his native land. Mr. Moore served his apprenticeship in the South Wales and Birmingham areas. Leaving England some 22 years ago, Mr. Moore first decided to acquire some American experience, and then crossed to South Africa, where by dint of enterprise he has established a large foundry capable of meeting any requirements which his customers, the gold mines, choose to impose upon him. His firm have just installed a chemical and physical laboratory, and after his return the ironfoundry is to be enlarged and modernised, if not entirely rebuilt.

Mr. Moore takes a keen interest in the local and national government, and will be Mayor of Benoni next year. Mr. Moore is staying at the Engineers' Club, Coventry Street, London, W.

MR. J. MCFARLANE, managing director of Palmers Shipbuilding & Iron Company, Limited, Jarrow-on-Tyne, has sailed on a business tour of the United States and Canada.

Original Makers of

McNeil's Patent Weldless Stamped Steel Ladles

1633

Three-Ton Ladle.

We also manufacture
built up
ladles to any capacity

CHARLES McNEIL LTD.,

Kinning Park Hydraulic Forge,

—— GLASGOW, S.1. ——

Telephone: Glasgow, Ibrox 820 & 821. *Telegrams: Macneil, Glasgow.*

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	62	5	0
Three months	63	5	0
Electrolytic	67	0	0
Tough	63	15	0
Best selected ..	64	5	0
Sheets	91	0	0
India	80	0	0
Wire bars ..	67	10	0
Do. Aug–Sept.	67	10	0
Do. Aug–Sept.	67	10	0
Ingot bars ..	67	0	0
H.C. wire rods	70	15	0
Off. av. cash, June	59	19	2¾
Do., 3 mnths., June	60	18	9
Do. Sttlmnt., June	59	18	9½
Do., Electro, June	63	11	5½
Do., B.S., June	63	1	11½
Aver. spot price copper, June	59	19	2¾
Do., wire bars, June	63	15	5¾
Solid drawn tubes			13d.
Brazed tubes ..			13d.
Wire			10d.

BRASS.

Solid drawn tubes	11¾d.
Brazed tubes ..	13¾d.
Rods, drawn ..	10½d.
Rods, extd. or rlld.	7½d.
Sheets to 10 w.g.	10½d.
Wire	10½d.
Rolled metal ..	9½d.
Yellow metal rods	7½d.
Do. 4 x 4 Squares	8d.
Do. 4 x 3 Sheets	8½d.

TIN.

	£	s.	d.
Standard cash	262	15	0
Three months ..	265	7	6
English ..	262	15	0
Bars	263	15	0
Straits	267	2	6
Australian .	264	17	6
Eastern ..	269	0	0
Banca	267	2	6
Off. aver. cash, June	252	11	8
Do., 3 mths., June	253	19	8¾
Do., Sttlmnt. June	252	12	7¾
Aver. spot., June	252	11	8

SPELTER.

	£	s.	d.
Ordinary ..	35	13	9
Remelted ..	34	10	0
Hard	29	0	0
Electro 99.9 ..	39	5	0
English ..	35	10	0
India	30	10	0
Zinc dust ..	42	0	0
Zinc ashes ..	14	10	0
Off. aver., June	33	17	4 13/14
Aver., spot, June	34	2	11¾

LEAD.

	£	s.	d.
Soft foreign ppt.	35	7	6
English ..	36	10	0
Off. average, June	33	4	6 9/14
Average spot, June	33	9	7

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	40	0	0
Do. V.M. ex whf.	40	0	0
Dutch		—	
Rods	46	0	0
Boiler plates ..	40	0	0
Battery plates	39	0	0

ANTIMONY.

	£	s.	d.
Special brands, Eng.	84	10	0
Chinese ..	68	0	0
Crude	53	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver ..	14	0	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro silicon
45/50% 13 0 0 to 13 5 0
75% 22 5 0
Ferro-vanadium—
35/40% 16/- to 17/- lb. va
Ferro-molybdenum—
70/75% c. free 7/- lb.
Ferro-titanium—
23/25% carbonless 1/- lb
Ferro-phosphorus, 20/25%, £22 0 0
Ferro-tungsten—
80/85 %, c.fr. 1/7 to 1/7½ lb.
Tungsten metal powder—
98/99% 1/10 to 1/11 lb.
Ferro-chrome—
4/6% car. .. £23 15 0
6/8% car. .. £23 0 0
8/10% car. .. £23 12 6
Ferro-chrome—
Max. 2% car. £42 15 0
Max. 1% car. £52 5 0
Max. 0.70% car. £56 10 0
70%, carbonless 1/5 lb.
Nickel—99%, cubes or pellets £170 to £175
Cobalt metal—98/99% 10/- to 10/3 lb.
Aluminium 98/99% £118
Metallic Chromium—
96/98% .. 3/9 lb.
Ferro-manganese (net)—
76/80%, loose £15 10 0
76/80%, packed £16 10 0
76/80%, export £15 0 0
Metallic manganese—
94/96%, carbonless 2/-lb.
Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

	s.	d.
Finished bars, 14% tungsten ..	2	6
Finished bars, 18% tungsten ..	3	0

Per lb. net, d/d buyers' works.
Extras—
Rounds and squares 3 in. and over .. 4d. lb.
Rounds and squares under ¼ in. to ⅛ in. 3d. lb.
Do. under ⅛ in. to ⅛ in. .. .. 1/- lb.
Flats, ½ in. × ⅛ in. to under 1 in. × ⅛ in. 3d. lb.
Do. under ⅛ in. × ⅛ in. 1/- lb.
Bevels of approved sizes and sections 6d. lb.
Bars cut to length 10% extra

Scrap from high-speed tool steel—
Scrap pieces .. 3d.
Turnings and swarf 1d.
Per lb. net, d/d steel makers' works.

SCRAP.

	£	s.	d.	£	s.	d.
South Wales— Hvy. steel	3	2	6 to	3	5	0
Bundled steel &shrngs.	3	0	0 to	3	3	6
Mixed iron & steel	2	17	6 to	3	0	0
Heavy cast iron	3	2	6 to	3	5	0
Good machinery for foundries ..	3	12	6			
Cleveland— Heavy steel ..	2	17	6			
Steel turnings ..	2	5	0			
Cast-iron borings	2	2	3			
Heavy forge ..	4	0	0			
Bushelled scrap	3	5	0			
Cast-iron scrap ..	3	11	6			
Lancashire— Cast-iron scrap ..	3	12	6			
Heavy wrought	3	12	6 to	3	15	0
Steel turnings ..	2	5	0			

London — Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean) ..	52	0	0
Brass (clean) ..	39	0	0
Lead (less usual draft)	31	0	0
Tea lead ..	27	0	0
Zinc	24	0	0
New aluminium cuttings ..	93	0	0
Braziery copper	47	0	0
Gunmetal ..	47	0	0
Hollow pewter ..	170	0	0
Shaped black pewter	123	0	0

PIG-IRON.

(f.o.t. unless otherwise stated).

N.E. Coast—
Foundry No. 1 .. 75/-
Foundry No. 3 .. 71/-
Foundry No. 4 .. 70/6
Forge No. 4 .. 70/-
Hematite No. 1 .. 77/6
Hematite M/Nos. .. 77/-
N.W. Coast—
Hem. M/Nos. d/d Glas. 88/-
,, d/d Birm. .. 95/-
Midlands—
Staffs. common* .. 102/-
,, No. 4 forge 70/-
,, No. 3 foundry 72/6
Shrops. basic .. 85/-
,, Cold blast, ord.* 190/-
,, ,, roll iron* 195/-
* d/d Birmingham.
Northants forge .. 60/-
,, fdry No. 3 .. 65/-
Derbyshire forge .. 66/3
,, fdry No. 3 .. 70/-
,, basic 72/6
Scotland—
Foundry No. 1 .. 86/6
,, No. 3 .. 81/6
Hem. M/Nos. .. 83/6
Sheffield (d/d district)—
Derby forge .. 70/-
,, fdry. No. 3 .. 74/-
Lincs. forge .. —
,, fdry. No 3 .. 78/-
E.C. hematite .. 87/-
W.C. hematite .. 92/6
Lincs. (at furnaces)—
Forge No. 4 .. —
Foundry No. 3 .. 72/-
Basic 72/-
Lancashire (d/d eq. Man.)—
Derby forge .. 74/3
,, fdry. No. 3 .. 77/6
Northants foundry No. 3 .. 78/-
Dalzell, No. 3 .. 111/6
Summerlee, No. 3 .. 99/-
Glengarnock, No. 3 99/-
Gartsherrie, No. 3 .. 99/-
Monkland, No. 3 .. 99/-
Coltness, No. 3 .. 99/-
Shotts, No. 3 .. 99/-

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£	s.	d.	£	s.	d.
Bars (cr.)	11	12	6 to	12	10	0
Angles		12	7		6	
Tees to 3 united ins		13	2		6	
Nut and bolt	11	15	0			
Hoops	14	0	0 to	15	0	0
Marked bars (Staffs.) f.o.t.	14	10	0			
Gas strip ..	13	0	0			
Bolts and nuts, ¾ in. × 4 in. ..	16	15	0			
Steel— Ship plates	8	15	0 to	9	0	0
Boiler plts.	£12	10	to	13	0	0
Chequer plts.	£10	10	to	11	0	0
Angles	£8	5	0 to	8	10	0
Tees	£9	5	0 to	9	10	0
Channels	£7	10	0 to	8	0	0
Joists	£8	5	0 to	8	10	0
Rounds and Squares 3in. to 5½in. ..		9	5		0	
Rounds under 3 in. to ⅜ in... ..		9	0		0	
Flats, over 5 in. wide and up ..		9	15		0	
Flats, 5in. to 1½in.		8	15		0	
Rails, heavy ..		8	10		0	
Fishplates ..		12	10		0	
Hoops (Staffs.)	£11	0	0 to	11	10	0
Black sheets, 24g.	11	10	0			
Galv. cor. sheets, 24g.		16	0		0	
Galv. fencing wire 8g. plain ..		14	0		0	
Billets, soft	6	10	0 to	7	15	0
Billets, hard ..		9	0		0	
Sheet bars	6	12	6 to	6	15	0
Tin bars d/d	6	12	6 to	6	15	0

PHOSPHOR BRONZE.

	Per lb.	basis.
Strip	1	2¾
Sheet to w.g. ..	1	3¼
Wire	1	3½
Rods	1	2½
Tubes	1	7
Castings	1	2

Delivery 3 cwt. free.
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
3/0 to 10 G. ..	1/6½ to 2/1½

with extras according to gauge.

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.	Dols.
No. 2X foundry, Phila.	21.26
No. 2 foundry, Valley	20.26
No. 2 foundry, Birm.	18.00
Basic	19.76
Bessemer	20.76
Malleable	20.26
Grey forge	19.76
Ferro-mang. 80% d/d	115.00
Bess. rails, h'y, at mill	43.00
O.-h. rails, h'y at mill	43.00
Bess. billets	35.00
O.-h. billets	35.00
O.-h. sheet bars ..	35.00
Wire rods	45.00
	Cents.
Iron bars, Phila. ..	2.22
Steel bars	2.00
Tank plates	1.90
Beams, etc.	2.00
Skelp, grooved steel ..	1.90
Skelp, sheared steel ..	1.90
Steel hoops	2.40
Sheets, black, No. 28 ..	3.10
Sheets, galv., No. 28 ..	4.15
Sheets, blue an'l'd, 9 & 10	2.30
Wire nails	2.65
Plain wire	2.50
Barbed wire, galv. ..	3.40
Tinplate, 100 lb. box ..	$5.50

COKE (at ovens).

Welsh foundry ..	37/6
,, furnace	27/6
Durham & North. ,, foundry ..	35/-
,, furnace ..	17/-
Other Districts, foundry	35/-
,, ,, furnace (Basis)	13/6

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes, box	20 × 14,	19/3
,,	28 × 20, ,,	38/6
,,	20 × 10, ,,	28/-
,,	18¾ × 14, ,,	20/1½
C.W.	20 × 14, ,,	17/7½
,,	28 × 20, ,,	35/4½
,,	20 × 10, ,,	24/7½
,,	18¾ × 14, ,,	18/1½

Terneplates 28 × 20, 1/3 per box basis below tinplates.

SWEDISH IRON.

Bars, hammered £19/0 to £20/0
Rolled Ord. £16/0/0 to £16/10/0
Nail rods 16 5 0 to £16 15 0
Keg. steel nom. £33 to £35
Faggot steel nom. £22 to £25
Blooms, according to quality £10 to £14
Pig-iron £6 15 0 to £7 0 0 all f.o.b. Gothenburg.

TUBES.

	Up to and incl. 6 in.
Gas .. 55%	Tube prices are now free.
Water .. 50%	
Steam .. 45%	

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.		
July 16	61	15	0	dec.	2/6
,, 17	61	17	6	inc.	2/6
,, 20	62	0	0	,,	2/6
,, 21	62	2	6	,,	2/6
,, 22	62	5	0	,,	2/6

Electrolytic Copper.

	£	s.	d.		
July 16	66	5	0	inc.	5/-
,, 17	66	10	0	,,	5/-
,, 20	66	15	0	,,	5/-
,, 21	67	0	0	,,	5/-
,, 22	67	0	0	No change	

Standard Tin (cash).

	£	s.	d.		
July 16	258	10	0	dec.	17/6
,, 17	260	15	0	inc.	45/-
,, 20	261	5	0	dec.	10/-
,, 21	261	7	6	inc.	2/6
,, 22	262	15	0	,,	27/6

Tin (English ingots).

	£	s.	d.		
July 16	258	10	0	dec.	20/-
,, 17	261	0	0	inc.	50/-
,, 20	261	10	0	,,	10/-
,, 21	261	10	0	No change	
,, 22	262	15	0	inc.	25/-

Zinc Sheets (English).

	£	s.	d.		
July 16	40	0	0	No change	
,, 17	40	0	0	,,	,,
,, 20	40	0	0	,,	,,
,, 21	40	0	0	,,	,,
,, 22	40	0	0	,,	,,

Spelter (ordinary).

	£	s.	d.		
July 16	34	15	0	inc.	1/3
,, 17	34	17	6	,,	2/6
,, 20	34	18	9	,,	1/3
,, 21	35	6	3	,,	7/6
,, 22	35	13	9	,,	7/6

Lead (English).

	£	s.	d.		
July 16	35	15	0	No change	
,, 17	35	15	0	,,	,,
,, 20	36	0	0	inc.	5/-
,, 21	36	5	0	,,	5/-
,, 22	36	10	0	,,	5/-

Exports of Iron Castings in June and the six months, 1925, compared with June and the six months, 1924.

	June, 1924.	June, 1925.	Six months, 1924.	Six months, 1925.	June, 1924.	June, 1925.	Six Months 1924.	Six Months 1925.
BUILDERS' CASTINGS—								
Stoves, Grates, etc., Cisterns, Baths, etc., and cooking and Washing Boilers:—	Tons.	Tons.	Tons.	Tons.	£	£	£	£
To Argentine Republic	103	81	628	770	3,731	2,927	23,252	26,908
,, British South Africa	301	369	1,500	1,877	10,269	12,389	53,571	66,862
,, ,, East Indies	132	136	857	897	4,619	5,995	29,121	43,069
,, Australia	61	26	389	384	3,572	1,765	22,179	21,077
,, New Zealand	95	216	974	1,378	4,516	9,786	47,046	64,772
,, Other Countries	513	629	3,066	3,849	25,180	31,473	151,795	194,902
Total	1,205	1,457	7,214	9,155	51,887	64,335	326,964	417,590
PIPES AND FITTINGS—								
Cast—								
To Argentine Republic	769	974	3,100	5,876	9,636	11,392	42,318	75,802
,, British South Africa	396	864	4,734	4,154	6,480	12,017	57,154	57,174
,, ,, India	1,125	718	6,055	5,690	17,695	10,239	90,117	80,968
,, Straits Settlements & Malay Sts.	611	385	5,145	3,149	7,919	4,255	63,850	36,640
,, Ceylon	77	223	575	789	1,215	2,400	7,980	9,787
,, Australia	510	539	2,372	1,996	7,630	8,594	35,481	30,405
,, Other Countries	3,465	4,793	18,072	28,168	57,207	72,503	301,771	419,586
Total	6,953	8,496	40,053	49,822	107,782	121,400	598,671	710,362
HOLLOW-WARE—								
Cast not Enmlled, & Cast, Tinned ..	488	666	3,127	4,298	17,621	22,818	125,905	140,431
,, Enamelled	74	60	569	505	7,170	7,655	58,257	50,793
CASTINGS, in the rough—								
Iron	154	246	654	754	5,476	7,906	27,088	28,500
Steel	71	66	1,760	278	1,459	3,600	27,683	11,867

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

18, BENNETTS HILL, BIRMINGHAM.

18, BENNETTS HILL, BIRMINGHAM.
11, OLD HALL STREET, LIVERPOOL.
EXCHANGE BLDGS., PORT TALBOT.
FOWLERS BUILDINGS, BOMBAY.
CLIVE STREET, CALCUTTA.
ANGAPPA NAICK STREET, MADRAS.

REGISTERED TRADE MARK

1, HONG KONG ROAD, SHANGHAI.
OCEAN BUILDING, SINGAPORE.
JAVA STREET, KUALA LUMPUR
5, SHAFFRAZ ROAD, RANGOON.
COX'S BUILDINGS, KARACHI.
P.O. BOX 1580, CAIRO.

PIG IRON

SCOTCH, MIDDLESBRO', HEMATITE, BASIC, SPECIALS, &c.,

NON-FERROUS METALS

COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

WILLIAM COLVIN & COMPANY,

ROYAL EXCHANGE, MIDDLESBROUGH.

93, HOPE STREET, GLASGOW.

SMALL ADVERTISEMENTS.

SITUATIONS VACANT AND WANTED.

ADVERTISER, holding Honours and Research degrees in Science, age 32, considerable technical and commercial experience, particularly in Non-Ferrous work, having been Works Manager and Research Metallurgist for several years, seeks position with progressive firm desiring to increase quality and quantity of output.—Apply, Box "C. Q.," Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

YOUNG MAN, having just completed University Course in Metallurgy, desires post, preferably Commercial; served proper apprenticeship to Founding; also experience of Machine Tools, Fitting, Cupola management, and some Electric Furnace practice; tall, of good appearance, and has sound general knowledge.—Box 398, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

GENTLEMAN, with 30 years' experience as Foundry Manager, seeks position as Instructor, Lecturer, Demonstrator on Foundry Practice; also Mixings of Non-ferrous Metals or Irons, Institutes, Schools or Works.—Box 400, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

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